Vol. 13 No. 1 FEBRUARY, 1950

TRANSACTIONS OF THE INSTITUTE of WELDING

(See Title page)

PUBLISHED BY

THE INSTITUTE OF WELDING (LTD.)

2, BUCKINGHAM PALACE GARDENS, LONDON, S.W.1.

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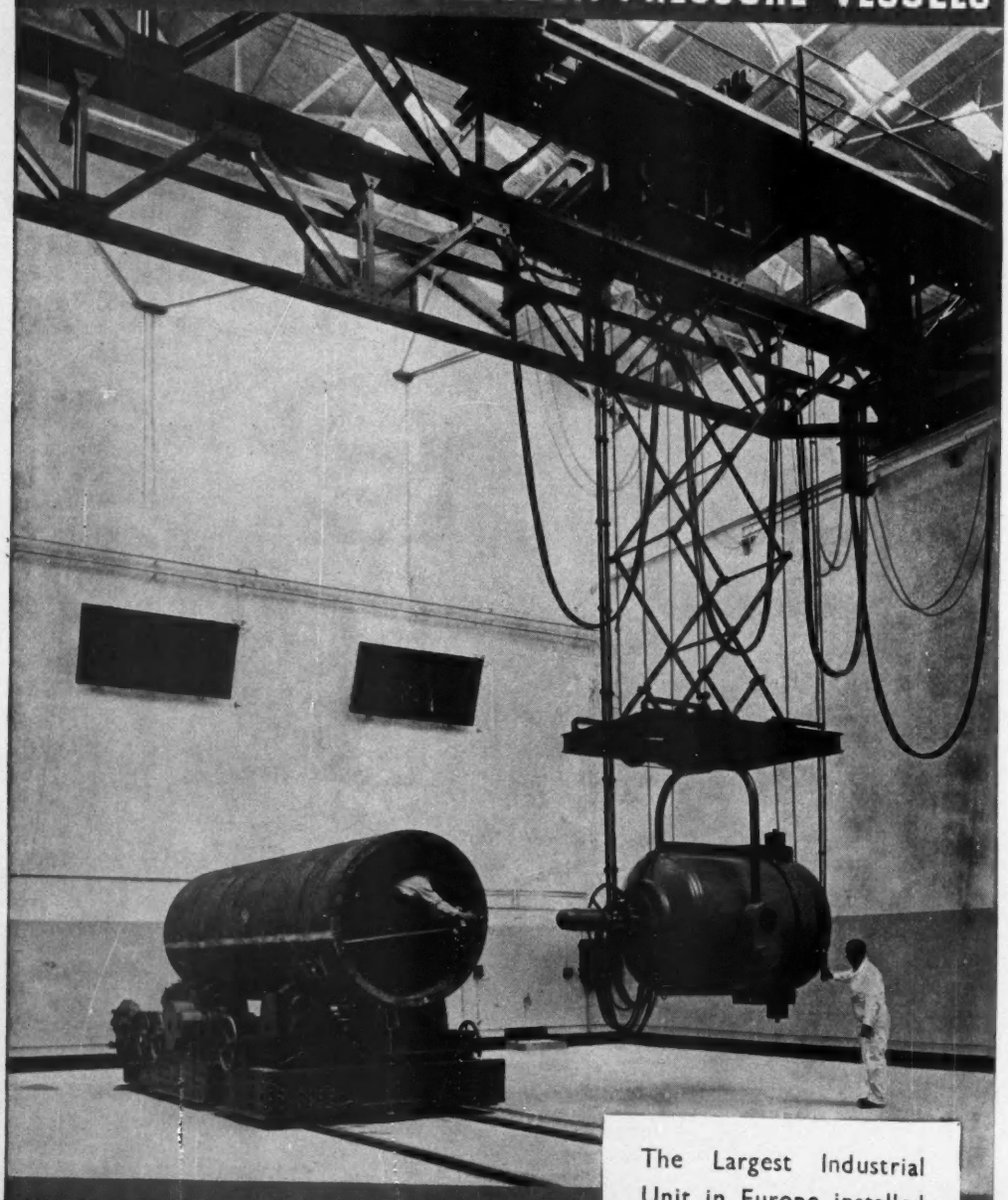

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THE INSTITUTE OF WELDING

Competitions

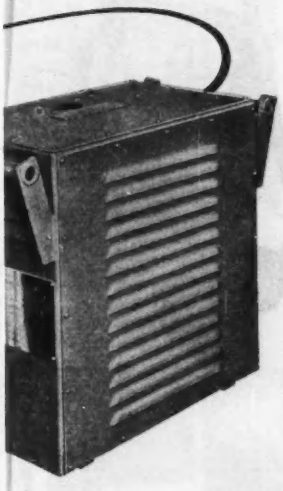
Regulations governing the award of prizes in competitions organized by the Institute.

I. The Sir William J. Larke Medal

1. The medal shall be awarded annually by the Council on the recommendation of a committee composed of the chairmen of the General Purposes Committee, the Education Committee, the Programme Committee, and the Technical Committee, or deputies nominated by them.
2. Before making their recommendation, the Committee shall examine :—
   (*a*) All papers read or communicated to the Institute by members during the previous session and unpublished at the time of reading or communication.
   (*b*) Papers read to the Branches of the Institute by members during the previous session and submitted by the Branch Committees for consideration, not more than one paper to be submitted by any one Branch Committee.
3. In considering the papers submitted to their judgment, the committee shall have regard both to the originality of their content and their effectiveness as expositions of their subjects.
4. No paper shall be considered which contains any advertising matter or commercial propaganda.
5. The Council reserves the right to withhold the award of the medal and of any prizes associated with the award, if no paper is judged by the adjudicators to be of sufficient merit.
6. Papers to be considered shall be submitted by 30 April and the adjudicating committee shall report to the Council at their autumn meeting.

II. C. W. Hill Prize

1. The Council of the Institute of Welding invite competition for the C. W. Hill Prize, endowed by Mr. C. W. Hill, A.M.I.E.E., M.I.Struct.E., a former President of the Institute.



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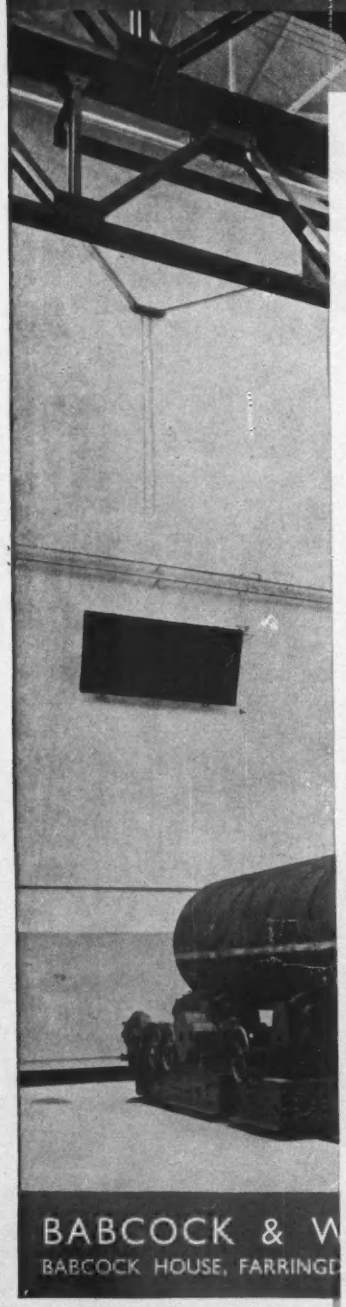

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2. The competition is open to *Students*, *Graduates* and *Associates* of the Institute. Each competitor may submit one entry only and competitors may not join together in submitting an entry.

3. The prize will consist of a set of drawing instruments of the approximate value of seven guineas. Certificates will be awarded to competitors whose entries, though not awarded the prize, are specially commended by the judges.
The Institute reserves the right to withhold the awards if papers of sufficient merit are not forthcoming.

4. Candidates are required to redesign for welded fabrication one of two designs supplied by the Institute or any riveted or cast object of their own selection. Entries must consist of sufficiently detailed arrangement drawings with design data showing the scantlings and weld details, and must also specify the materials candidates propose to employ in the design.
Drawings must be accompanied by notes up to 500 words, describing and explaining the principles of approach for the design, with sketches and/or diagrams as considered necessary. The principal reasons should be stated for such features of the design as concern economy, accessibility for welding for final machining and/or pre-machining, and methods of controlling distortion in final assembly if the design embodies this procedure. Competitors who choose to redesign an object of their own choice must also attach sketches of the original with their papers. A competitor who submits a redesign of an object of his own choice may be required to produce satisfactory evidence that it is his own work.

5. Students, Graduates and Associates will be informed individually as soon as details of the competition in any year are available. Those who wish to enter, on making written application to the Secretary of the Institute, will be sent copies of the designs to be supplied by the Institute, and particulars of the size of drawings which they should submit for the competition.

6. All papers submitted for the competition must reach the Secretary of the Institute not later than 31 October in any year.

7. Any written matter must be submitted in the same parcel as the drawings. No name must appear on the drawings or written matter, which should be attached together, but inside the parcel there must be a slip giving the candidate's name, address and class of membership, in a sealed envelope. The parcel should be addressed to the Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1. If acknowledgment of receipt is required, a separate covering letter must be sent with the entry and envelope.

8. A paper which has gained the prize in the competition in one year shall not be eligible for the prize in the following or succeeding years.

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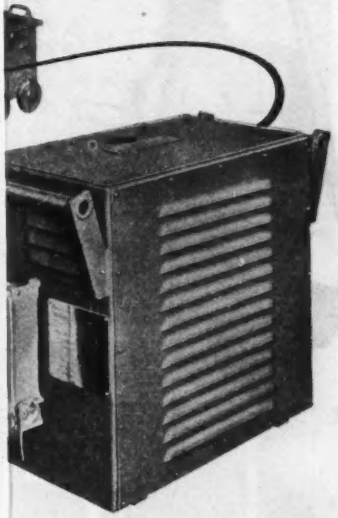

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arbon arc process

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9. The Institute reserves the right at the discretion of the Council to publish the paper for which the prize is awarded, and a competitor will be held to have agreed to this condition by the act of submitting a paper.

10. Copyright of the paper for which the prize has been awarded shall be vested in the Institute of Welding.

11. The decision of the Committee of Judges shall be final.

III. B.O.C. Welding Prize

1. In 1948 the Council of the Institute of Welding accepted a gift of £100 a year for three years (1949, 1950 and 1951) from the British Oxygen Company Ltd. to provide a prize fund for competition among members of the Institute, with a view to stimulating interest in the development of gas welding and cutting and allied processes.

2. The Council have asked the Committees of the Branches of the Institute to organise competitions among their members in the years 1950 and 1951. Papers submitted for the competition will be collected by the Branch Committees and forwarded for examination by a Committee of Judges appointed by the Council.

   First, second and third prizes of £30, £20 and £10 may be awarded at the discretion of the judges, as well as other monetary prizes according to the number and quality of the entries received. The total value of the prizes awarded in any one year may not exceed £100.

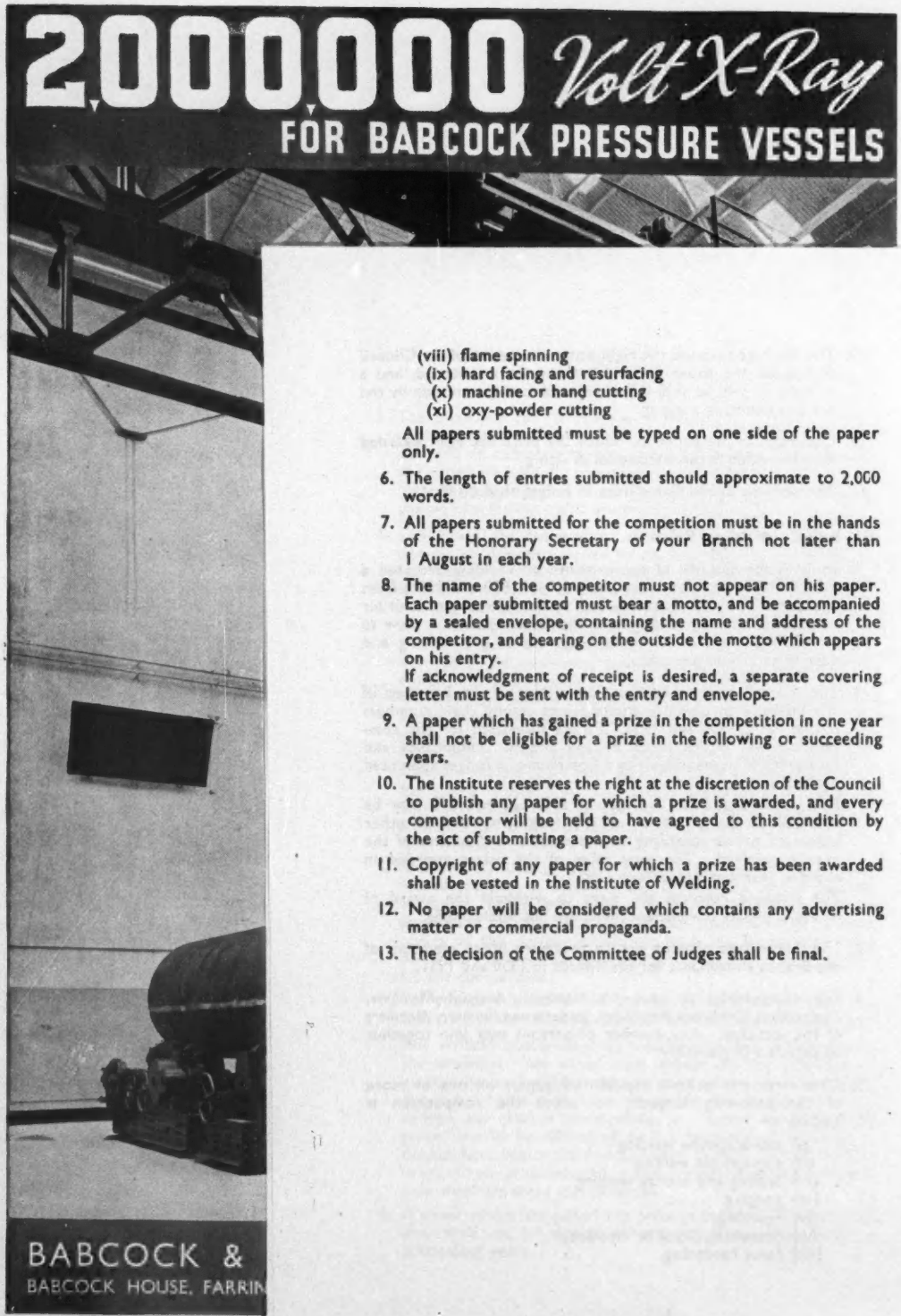
   The Institute reserves the right to withhold the award of prizes, if papers of sufficient merit are not forthcoming.

3. The Committee of your branch therefore invite members of the Branch to compete for the awards in 1950 and 1951.

4. The competition is open to *Members*, *Associate-Members*, *Companions*, *Graduates*, *Associates*, *Students* and *Honorary Members* of the Institute. Any number of persons may join together to submit a single entry.

5. Candidates may submit unpublished papers on one or more of the following subjects, to which the competition is limited :—

   (i) oxy-acetylene welding
   (ii) oxy-fuel gas welding
   (iii) brazing and bronze welding
   (iv) gouging
   (v) descaling
   (vi) deseaming (hand or machine)
   (vii) flame hardening



(viii) flame spinning
(ix) hard facing and resurfacing
(x) machine or hand cutting
(xi) oxy-powder cutting

All papers submitted must be typed on one side of the paper only.

6. The length of entries submitted should approximate to 2,000 words.

7. All papers submitted for the competition must be in the hands of the Honorary Secretary of your Branch not later than 1 August in each year.

8. The name of the competitor must not appear on his paper. Each paper submitted must bear a motto, and be accompanied by a sealed envelope, containing the name and address of the competitor, and bearing on the outside the motto which appears on his entry.
If acknowledgment of receipt is desired, a separate covering letter must be sent with the entry and envelope.

9. A paper which has gained a prize in the competition in one year shall not be eligible for a prize in the following or succeeding years.

10. The Institute reserves the right at the discretion of the Council to publish any paper for which a prize is awarded, and every competitor will be held to have agreed to this condition by the act of submitting a paper.

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12. No paper will be considered which contains any advertising matter or commercial propaganda.

13. The decision of the Committee of Judges shall be final.

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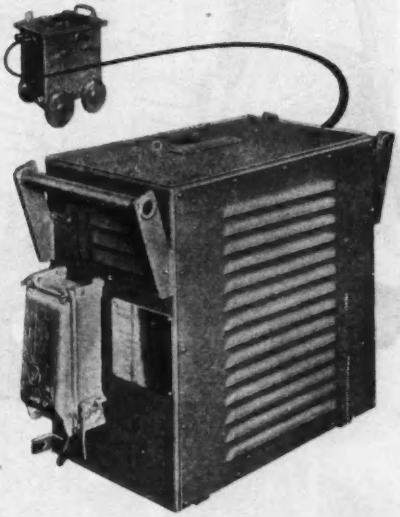

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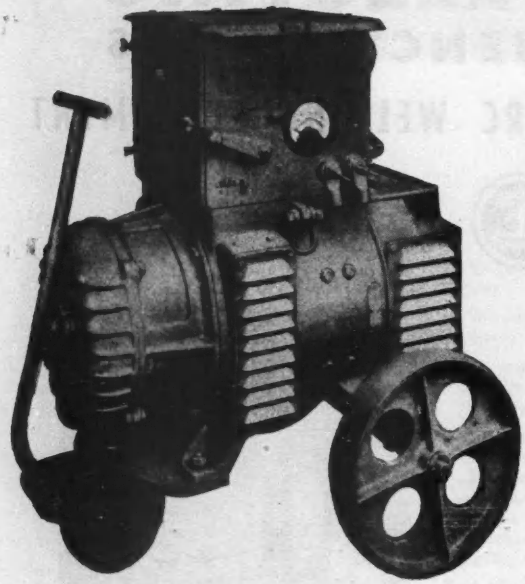

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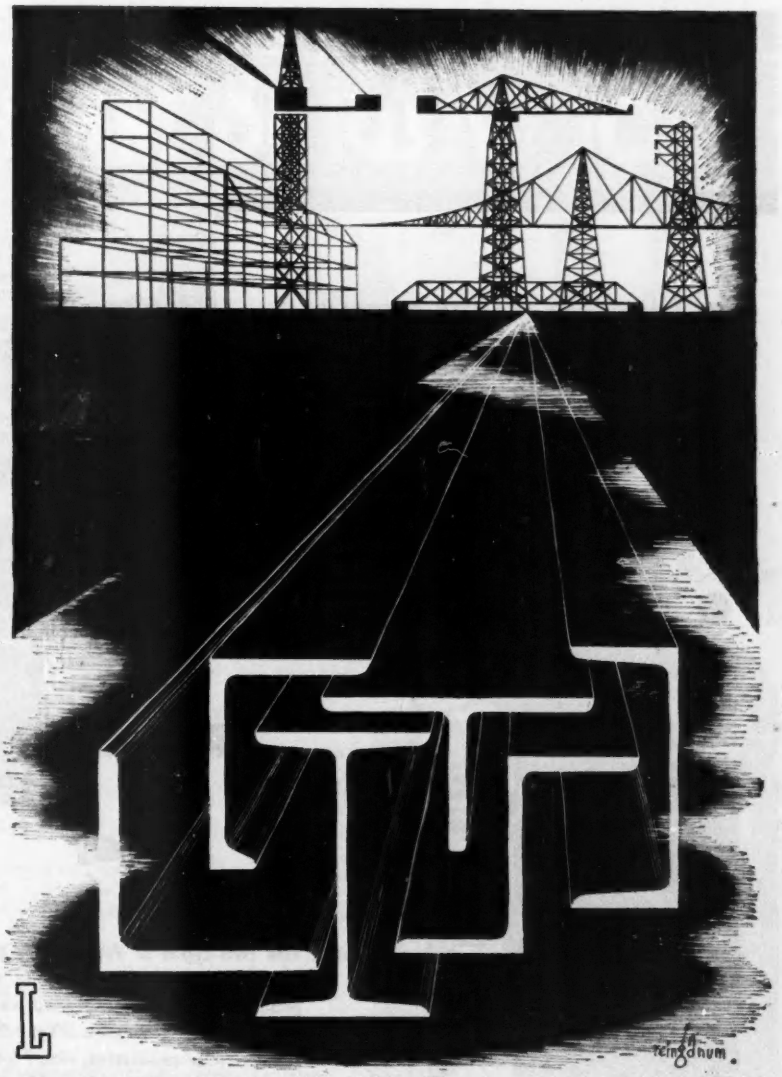

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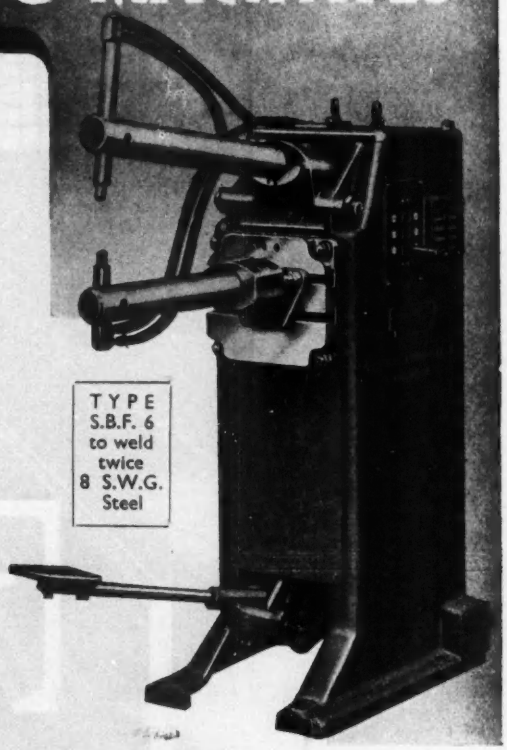
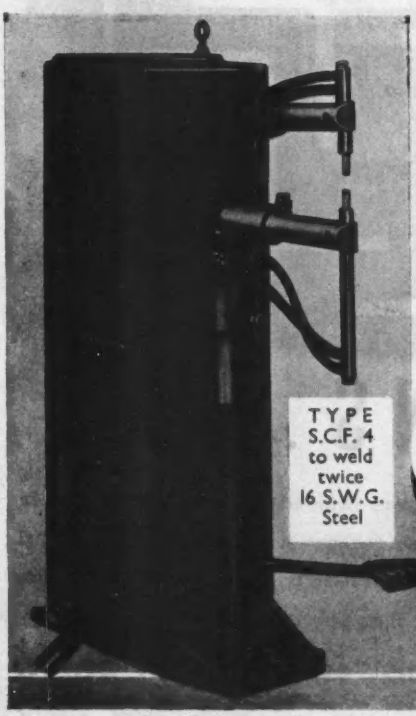


TYPE S.B.F. 6 to weld twice 8 S.W.G. Steel



TYPE S.C.F. 4 to weld twice 16 S.W.G. Steel

The two types of Woodhouse & Mitchell Spot Welders here illustrated are essentially practical machines designed and built for hard work and long service. Type S.C.F 4 has two transformer capacities, viz., 7.5 and 10 KVA; and Type S.B.F. 6 has three, 20, 30 and 40 KVA. Both types have throat depths up to 24 inches.

Illustrated descriptive matter on request

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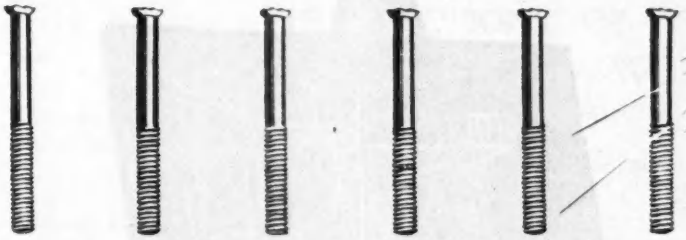

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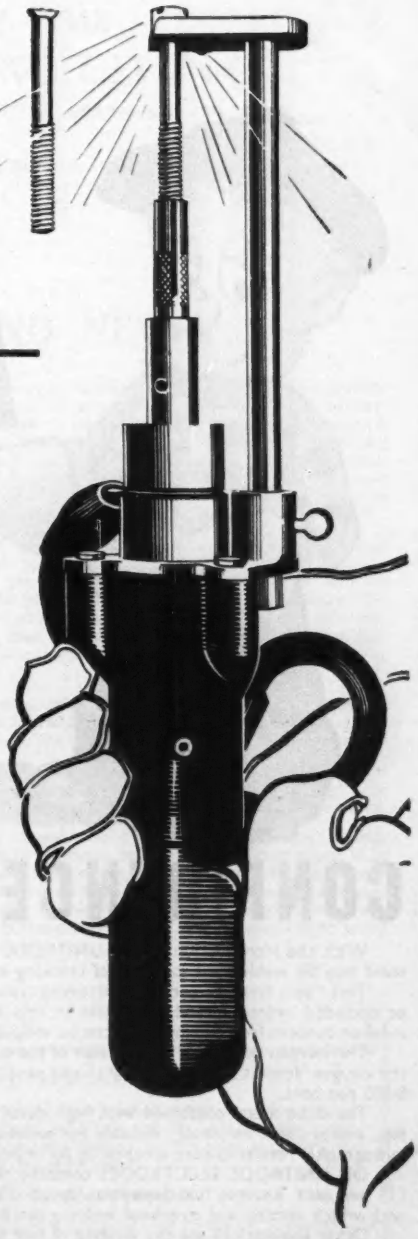
when you weld studs like a shot



With the Nelson stud welding gun you can weld studs to steel in any position—on horizontal and on vertical surfaces and even over-head. This modern method is 14 times faster than drilling and tapping because it is almost completely automatic. The equipment comprises a Nelson gun, automatic timer and D.C. generator. Operation is simplicity itself. Just load the 'gun,' hold it in position and fire—the equipment does the rest, in a split second. Nelson studs are so easy to fix that you can use them in place of bolts, pins and rivets. And every stud weld is neat, uniform and immensely strong. One secret of success in Nelson stud welding is the use of studs which are specially designed for the purpose. Nelson studs are made from specially selected steel, end-loaded with just the right amount of flux and sealed over like cartridges.

If you have a job for studs send for the Nelson brochure, which tells you all about this time-saving, cost-cutting technique.

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This "lime ferritic" (or low hydrogen) type electrode produces a weld metal so clean and free from slag inclusions or occluded hydrogen, and insensitive to impurities in the parent metal, that . . . as an extreme example . . . high sulphur content free cutting steel can be welded to cast steel without cracks in the weld.

The oxygen content is an indicator of the quantity of slag particles present. With the usual rutile type of electrode the oxygen deposit is, say, about 0·15 per cent., whereas with OK UNITRODE ELECTRODES this is reduced to about 0·035 per cent.

The clean metal combined with high ductility (36 per cent. on 3·54" diam.) and an Izod impact value of 80/100 ft., lbs., makes them eminently suitable for welding pressure vessels, rigid structures, pipe lines, etc., and the first-class radiographic results ensure acceptance by inspecting authorities.

OK UNITRODE ELECTRODES combine the above advantages with ease of use, and the high metal recovery of 115 per cent. ensures fast deposition speed. Clear visibility of the crater edge also contributes to the extreme ease with which vertical and overhead welding can be carried out.

Other applications are the welding of tool steel, cast steel, low grade steel, malleable iron, etc.

Further interesting information concerning OK UNITRODE ELECTRODES is contained in our Leaflet No. 48, which we shall be pleased to send upon request.

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TRANSACTIONS OF THE
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Vice-President : C. S. MILNE. PRESIDENT - O. V. S. BULLEID, C.B.E., M.I.Mech.E. *Secretary :* G. PARSLOE, B.A.

Honorary Editor : D. S. WATT, B.Sc., M.I.N.A.

VOL. 13 NO. 1 FEBRUARY, 1950 PRICE 7s. 6d.

INSTITUTE NOTES AND NEWS

The First £5,000.—Donations and promises for the Working Reserve Fund, for which the President appealed to members in the Autumn, are now approaching £5,000. Already, therefore, the reserves of the Institute have been trebled and the Council and its Finance Committee, for the first time, are able to plan ahead without pressing anxiety as to the security of the Institute.

Many Branch Chairmen have written to their members, reinforcing the President's appeal, and the topic has naturally been prominent in the speeches made at Branch functions.

In some quarters members have urged that the membership subscriptions should again be increased, in order to provide a reasonable yearly surplus, which could be put by to form the reserve. The Finance Committee believe that this idea would not be acceptable to most members, but it shows that those who hold it realise that the Institute at present returns to its members in the form of services a larger proportion of their subscriptions than is wholly prudent, and that the maintenance of an Institute as active and aggressive as the Institute of Welding upon subscriptions so low as those at present in force is, in itself, an achievement.

The Institute, of course, has no premises of its own, its present offices being held on a lease which will expire in about ten years' time. A considerable sum will certainly be needed then, even if the Council is only to obtain premises equal to those now occupied by the Institute, and a very much larger sum would be needed to buy outright a house which could accommodate meetings, a most desirable thing.

Change of Title.—The resolutions proposed by the Council and circulated to all corporate members were adopted at the Extraordinary General Meeting on 25 January last. As explained in the memorandum accompanying the resolutions, a large number of the amendments to the Memorandum of Association and the Articles of Association are legal technicalities, necessary to bring the Constitution of the Institute into line with the Companies Act, 1948. One important change is that of title, which is now "The Institute of Welding," without the addition of the words "Limited by Guarantee."

Incidentally, the name causes some confusion in international welding circles, because there is only one Institute of Welding, though there are several bodies similarly named but with the addition of the name of the country in which they operate. The representatives of our Institute are inclined to be a little self-satisfied about this, and to say, at least among themselves, that the British welding society is *The* Institute of Welding!

Spring Meeting, 1950.—Arrangements for the Spring Meeting of 1950, to be held in Birmingham and Wolverhampton, are now nearly completed. The following is an outline of the programme:—

Tuesday, 25 April (morning and afternoon).—Conference of Branch Officers at the Grand Hotel, Birmingham; (*evening*) Civic Reception at the Council House by the Lord Mayor of Birmingham.

Wednesday, 26 April (morning).—"Birmingham Day." Lecture meeting at the Grand Hotel, Birmingham. Details of papers to be announced later; (*afternoon*) choice of works visits: (1) General Electric Co., Witton; (2) Metropolitan-Cammell Carriage & Wagon Co. Ltd., Saltley; (3) Joseph Lucas Ltd.; (*evening*) choice of visit to Shakespeare Memorial Theatre at Stratford-on-Avon by motor

OXY-ACETYLENE FLAME GOUGING—A HIGHLY VERSATILE PROCESS

FRONT COVER ILLUSTRATION.—With the aid of a specially designed nozzle, the Oxy-acetylene Flame Gouger cuts a groove in the surface of steel; it does everything a chisel can do—many times faster, more economically, yielding better results. Applications include the removal of weld defects, tack welds, lugs and cleats; the dismantling of welded structures; the elimination of cracks; maintenance and scrapping operations. Plate edges can also be prepared.

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coach or a Welding Brains Trust meeting at the Grand Hotel, Birmingham. Further particulars to be announced later. A whole-day coach tour has been arranged for ladies, calling at Warwick and arriving at Stratford-on-Avon for lunch. The ladies will be shown various places of interest during the afternoon and will be able either to return to Birmingham for the evening or to remain with the theatre party at the Shakespeare Memorial Theatre.

Thursday, 27 *April* (*morning*).—"Wolverhampton Day." Lecture meeting at the Victoria Hotel, Wolverhampton. The following papers will be presented:—"Some Aspects of Fusion Welding for the Chemical and Food Industries," by F. Jukes; "The Welding of Pressure Vessels," by S. H. Griffiths, A.I.M.; luncheon at the Victoria Hotel, at which the Mayor of Wolverhampton will be the principal guest; (*afternoon*) choice of one of the following works visits: (1) John Thompson (Wolverhampton) Ltd.; (2) Thompson Bros. (Bilston) Ltd. Ladies, who will be welcome at the luncheon, may make a coach visit to Bridgenorth, returning to Wolverhampton in time to join the gentlemen for the return to Birmingham after tea; (*evening*) dinner at the Grand Hotel, Birmingham, at which the Lord Mayor and Lady Mayoress of Birmingham will be the principal guests.

Friday, 28 *April* (*morning*). Choice of one of the following works visits: Austin Motor Co. Ltd., Longbridge; Cadbury Bros. Ltd., Bourneville.

International Welding Congress.—The five British member societies of the International Institute of Welding, namely, the British Acetylene Association, the Welding Sections of the British Electrical and Allied Manufacturers' Association, the British Welding Research Association, the Institute of Welding and the Sheet and Strip Metal Users' Technical Association, have set up a Joint Committee to organise the meeting of the International Institute of Welding in Great Britain in 1951. The Committee held its first meeting in January, established an Executive Committee and discussed outline plans, which will be put before the Bureau of the International Institute in March.

The aim is to hold a Congress, of which the annual meeting of the International Institute would form a part, but the character of the meeting will necessarily depend upon the funds available. In this connection the President of the Institute, Mr. Bulleid, is appealing to industry on behalf of the five member societies for contributions to a guarantee fund of £5,000. If this amount is forthcoming, it will be possible to organise a Congress lasting a week with a membership of perhaps 400 and with a series of works visits in the following week to all parts of the country.

Welding of Light Alloys.—There was a good attendance at the meeting of the Institute on 25 January in London, when Mr. W. K. B. Marshall, Deputy Director of the British Welding Research Association, gave a paper entitled "The Welding of Light Alloys in Structural and Similar Applications." The Chair was taken by the President, who, in introducing Mr. Marshall, mentioned Ihat he was the winner of the Sir William J. Larke Medal of the tnstitute in 1945. The lecture dealt particularly with the metallurgical aspects in the welding of the higher strength aluminium-magnesium alloys and the heat-treated alloys. We hope to publish it in a later issue.

B.O.C. Welding Prizes.—Regulations for the B.O.C. welding prize 1950 have now been approved and are as follows:—

1. In 1948 the Council of the Institute of Welding accepted a gift of £100 a year for three years (1949, 1950 and 1951) from the British Oxygen Company Ltd. to provide a prize fund for competition among members of the Institute, with a view to stimulating interest in the development of gas welding and cutting and allied processes.
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12. No paper will be considered which contains any advertising matter or commercial propaganda.
13. The decision of the Committee of Judges shall be final.

Handbook for Welded Structural Steelwork.—A revised reprint of the *Handbook for Welded Structural Steelwork*, which has been in the press for nearly two years, is at last available, price 10s. per copy, post free. The book incorporates a number of important corrections to the formulæ on pages 111-118 of the fourth edition, but is otherwise identical with that edition. It is intended to circulate the corrections to the purchasers of the fourth edition.

Reading of Papers.—Members of the Institute who would be prepared to read papers at meetings of the Institute or of its Branches are invited to forward the papers (or descriptive summaries) for consideration by the Programme and Journal Committee. Papers submitted in response to this invitation should reach the Secretary of the Institute not later than 15 April, 1950.

Research Supplement.—With this issue of *Transactions* is included Volume 4, No. 1, of *Welding Research*, containing the following reports of the British Welding Research Association:—

Memorandum on Faults in Arc Welds in Mild and Low Alloy Steels.

A Review of Selected Papers on the Flash and Butt Welding of Light Alloys.

Binding of "Transactions."—The Index to Volume 12 of he *Transactions* for the year 1949 is printed in this issue. Members who wish to have their copies bound should detach the index before sending the parts of the 1949 volume to the binder. Arrangements have been made for the binding of members' volumes of *Transactions* in black embossed leather-cloth at a cost of 10s. 6d. each, plus 1s. for postage and packing. Members wishing to take advantage of this arrangement should forward parts, with index, to Mansell (Bookbinders) Ltd., 31, Cursitor Street, Chancery Lane, London, E.C.4.

Examination Regulations.—Copies of the following document are available gratis to members on application to the Secretary of the Institute:—"Examination Regulations and Syllabuses."

BOOK REVIEW

"Welding Technology," by F. Koenigsberger, pp. viii, 280, illus. 8to, Cleaver-Hume Press Ltd., 1949.

The author is to be congratulated on having given in the small compass of 280 pages a comprehensive account of the numerous welding systems which are now available to the engineering industry. The scope of the book is, however, even wider and ranges over all responsibilities of the welding engineer in the shop. The clarity with which this theme is expounded and the use of clear diagrams and annotated photographs set a high standard of technical writing which might well serve as an example to others. It will undoubtedly be regarded as a useful textbook for the student, a convenient reference for the engineer and a helpful manual for all those directly engaged in welding, particularly so in view of the wealth of information about electrodes, machine settings etc., given in tables and taken from authoritative sources. For those who seek more specialised knowledge there are numerous references to recent research reports and to detailed accounts of modern methods and equipment.

The general scheme of the book is an aid to easy reading and quick reference. The first chapter contains a summary of methods of welding used successfully in general engineering: oxy-acetylene welding; electric welding, including carbon-arc, argon-arc and metal arc; atomic hydrogen welding; thermit welding; blacksmith welding and resistance welding covering spot, seam, projection, butt and flash-butt welding. In the next two chapters entitled "Fusion Welding Processes" and "Forge Welding Processes," each of the above methods is described in detail. After a discussion of their suitability for the welding of ferrous and non-ferrous materials, there are three most valuable chapters dealing with the plant and equipment for oxy-acetylene, arc and resistance welding. The intricacies of the electrical machines and of electronic control gear are simply and clearly explained, though the student might profitably refresh his memory of the elements of these subjects beforehand. Flame cutting and gouging have a chapter to themselves, also welding manipulators and fixtures; the author wisely refrains from giving numerous examples of the latter and concentrates on the general factors which affect their design and use. Safety precautions, protective and welfare equipment are described and there is some useful information about the maintenance of plant. Distortion and residual stresses are dealt with from the practical point of view, the emphasis being on methods of avoiding trouble of this kind, or at least of reducing it to a minimum. The chapter on strength and faults in welding, while containing all that is essential, might well have been amplified, for instance by giving some examples of fatigue failures and a little more information about non-destructive methods of testing. No doubt the author considered that the book would be incomplete without some reference to design but a single chapter on this subject seems inadequate; on the other hand any expansion of this section might be regarded as departing too far from the main theme. Some notes on estimating make up the final chapter.

In these days when welding is developing so rapidly such a book comes as a welcome and timely addition to technical literature. It compares favourably with similar works being produced in other countries and is to be recommended as the work of an author whose experience embraces both teaching and responsible industrial practice.

J. W. R.

The Institute of Physics has launched as a monthly journal the *Journal of Applied Physics*, of which the first issue appeared in January. To this issue Sir Philip Morris contributes a special article on "A Scientific Education," and Mr. J. Moore one on "Some Chemical and Physical Properties of Rubber." The original contributions are as follows:—"The Development and Deionization Time of Heavy-Current a.c. Arcs" by J. S. Forrest, "The Measurement of Opacity and Reflectivity for Printing Papers" by V. G. W. Harrison and S. R. C. Poulter, "The Measurement of the Coefficient of Internal Friction of Solid Rods by a Resonance Method" by W. Lethersich and H. Pelzer, "The Application of Multiple Factor Analysis to Industrial Test Data" by R. Harper, A. J. Kent and G. W. Scott Blair, and "Note on the Interpretation of Multiple Factor Analysis" by A. J. Kent. There are also reviews of new books and notes and news. The Journal is published by the Institute of Physics and the subscription is £3.

The Central, the journal of the old students of the City and Guilds College, issued its hundredth number in December last. The occasion was marked by the contribution of a foreword by the Lord Mayor of London, greetings from the City Guilds, from the authorities of the Institute and the College, the Association of Old Students and from a number of eminent old students and past editors of the journal. For the first time also the journal appeared in its new cover, designed by Mr. H. Wilkinson, which incorporates in colour the arms of the Corporation of London and of the twelve Livery Companies. We offer our congratulations to the Editorial Board upon their centenary issue.

L. Aitchison and V. Kondic. *The Non Ferrous Metal Industry in Germany during the Period* 1939-1945. British Intelligence Objectives Sub-Committee Surveys, Report No. 23. 1949. 198 pp. London: H.M. Stationery Office. 3s. 6d.

After the war, a large number of teams visited Germany (under the auspices of British, American and joint official agencies) to investigate German industry, and their findings were embodied in numerous reports (C.I.O.S., B.I.O.S., F.I.A.T., and J.I.O.A. series). They were of unequal quality, and moreover some of them dealt with a variety of topics. This has militated against their use in the most advantageous way. Now Professor Aitchison and Dr. Kondic have prepared the present concise summary of the reported information, covering all aspects, from smelting onward, of the light, base, rare and precious metals; each section is followed by a list of relevant reports, and an index is provided.

This, however, is only part of the story of German war-time metallurgy. To complete the picture, reference must be made to the *F.I.A.T. Review of German Science*, 1939-1946. *Non Ferrous Metallurgy*, Parts I and II, which is a similar survey (*in German*) of published German scientific work in metallurgy. (For copies of the F.I.A.T. Reviews, application should be made to Board of Trade, Technical Information and Documents Unit, 40, Cadogan Square, London, W.1.)

BRITISH STANDARD

The following British Standard Code of Practice has now been issued:—321.102 (1950)—Installation and Maintenance of Electrical Machines, Transformers, Rectifiers, Capacitors and Associated Equipment. Copies are obtainable from the British Standards Institution, 24-28, Victoria Street, London, S.W.1. price 4s. post free.

EDUCATIONAL TRAVEL FOR ENGINEERS

In order to provide facilities for those engaged in the engineering and allied industries to travel abroad inexpensively for the improvement of their technical and general knowledge, and to foster improved trade relations, the Engineers' Educational Travel Club (Westminster) Ltd., has been formed. Membership of the Club is open to all those engaged in the engineering and allied industries for an annual subscription of 7s. 6d. (5s. for those under twenty-one years of age). There is also company membership at 3 guineas a year for firms which wish to send representatives abroad. Members travelling under the auspices of the Club may take friends and relations on the tours, and there are arrangements for monthly payments toward cost of tours. Full particulars may be had from the Secretary of the Club at 35, St. George's Square, Westminster, S.W.1.

ACTIVITIES IN THE BRANCHES

East of Scotland.—Mr. F. G. Bennett, Vice-Chairman, presided at the meeting on 28 October in the Edinburgh Chamber of Commerce, at which Mr. E. J. M. Mitchell presented a paper entitled "Weldability—Can it be Welded?" The paper was of exceptional interest to the large audience and provoked considerable discussion, in which it was agreed that the metallurgical aspects of welding should receive increasing attention in papers delivered to the Institute. We hope it may be possible for us to publish an abstract of the paper in a later issue.

The Dundee section of the Branch held two very well-attended meetings on 7 October and 4 November, at both of which the Chair was taken by Mr. G. Burnham. At the first Mr. F. Koenigsberger lectured on "Welding Procedure in General Engineering—its Advantages and Limitations," dealing with materials suitable for use in fabrications; the advantages of welded construction compared with cast and riveted structures; the necessity for concise instruction from the drawing office and also structures that were quite unsuitable for fabrication at economic prices.

The second meeting took the form of a brains trust, with Mr. T. Fisk as question master and the following as the trust:—Messrs. R. D. Berry, R. N. Low, J. Wheeland and D. W. Wright. As usual, this procedure proved very popular with members and the closure of the meeting left many questioners still waiting for their turn.

About 30 members of the Branch were privileged to visit the works of Messrs. Bruce Peebles & Co.Ltd., Pilton, Edinburgh, on the afternoon of 20 December last. The visitors were much impressed by the lay-out and equipment of the recently extended welding shop, where a great variety of fabricated products is in production. Appreciation of the arrangements made for the visit and of the Company's hospitality was expressed by the Branch Chairman, Mr. Stoddart, and acknowledged by the Company's Superintendent of Fabrication, Mr. Gilbert Anderson.

Birmingham Branch.—The Annual Dinner, held at the Grand Hotel, Birmingham, on Friday 25 November last, was attended by well over 200 members and guests, and was in every way a splendid occasion, worthy of its predecessors.

The Chairman of the Branch, Mr. R. E. G. Weddell, presided, and the principal guest was the Lord Mayor of Birmingham, Alderman H. Humphreys, J.P., who responded to the toast of the City of Birmingham proposed by the Secretary of the Institute, Mr. G. Parsloe. The toast of the Institute of Welding and the Birmingham Branch was proposed by Mr. R. A. Riddles, C.B.E., of the Railway Executive, and the President of the Institute, Mr. O. V. S. Bulleid, C.B.E., replied. The Chairman proposed the toast of the Kindred Associations and Visitors, to which Mr. H. G. Manzoni, Birmingham City Surveyor, responded.

Leeds.—The annual dinner of the Leeds and District Branch, held at the Guildford Hotel, Leeds, on 19 January, was a very successful function. The Chair was taken by the Branch Chairman, Mr. C. E. Rhodes, and the Branch President, Mr. A. J. Butterfield, proposed the toast of the City of Leeds, to which the Lord Mayor, Alderman N. D. Vine, J.P., replied. The Vice-President of the Institute, Mr. C. S. Milne, replied to the toast of the Institute of Welding, proposed by Mr. E. C. White, Chairman of the Yorkshire Branch of the Institution of Mechanical Engineers. Other speakers were Mr. W. Swan, who proposed the toast of the Guests, Mr. F. B. Maxwell, Vice-President of the Victoria Branch of the Australian Welding Institute, and Mr. W. F. Smith, Vice-Chairman of the North Midlands Branch of the Institution of Electrical Engineers.

Mr. Berry, the Honorary Secretary of the Branch, who had left his bed to attend the function, was warmly congratulated and thanked by members and guests for a splendidly organised dinner.

Liverpool.—The Liverpool Branch continues to distinguish itself by the issue of its Branch circular, No. 5 of which, issued in January 1950, contains the usual assortment of Branch news and notices, with strong support for the President's appeal for a working reserve fund.

The Branch reports a very successful discussion night on 11 October last, when the Vice-Chairman, Mr. John Wilson, presided and the meeting was opened by Principal R. R. Butler of the Liverpool Technical College, who spoke on research. His concluding question on the advantages of the argonarc method of welding aluminium opened a topic which succeeding speakers found much to their taste, the concensus of opinion seeming to be that this process is the answer to the troubles experienced with aluminium in the past. The report shows that some familiar topics were again under debate, such as the ignorance of welding practice among draughtsmen trained in the riveting tradition, and the need for special sections for welding. The British Oxygen Company's film, "Oxygen in Industry," was shown in the latter half of the meeting.

At the meeting on 8 November, Professor W. J. Kearton gave a most interesting and indeed an exciting lecture and demonstration on the "Application of Photo-Elasticity to the Measurement of Stresses." The Vice-President of the Institute, Mr. C. S. Milne, with the Secretary, Mr. G. Parsloe, was present at this lecture, and expressed the thanks of the audience to the lecturer for opening an unfamiliar and little understood method to the Branch.

Liverpool also reports, with justifiable pride, the part taken by its President, Mr. George Davenport, in opening the new Medway section of the Institute, and by its Chairman, Mr. G. A. O. Pridgeon, in delivering the first lecture to the new Preston section, to both of which reference is made elsewhere in this issue.

A novelty announced in the Branch circular is that on 10 June next members of the Wolverhampton Branch are to visit the Liverpool Branch with their ladies. We shall look forward to hearing more of this later on.

Manchester.—"Where Welding Wins" was the subject of Mr. D. W. Low's lecture at the Manchester College of Technology on 5 October. The lecturer, who was associated with the Mulberry harbour project, explained that his paper was based entirely on work carried out in the last three years and was intended to describe how the use of welding had grown in the dredge building industry. The process described was manual metallic arc welding. Mr. Low pointed out that welded mild steel fabrications have replaced many components previously designed as riveted steel structures, timber erections and iron or steel castings.

Dividing his paper into two sections, headed respectively "Why Welding Wins" and "Where Welding Wins," Mr. Low observed that in spite of some misgiving among shipbuilders and ship owners about welding of hull structures, dredging circles were more ready to accept welding, because of the enormous assistance which it offered in the maintenance of dredge craft and their equipment. The repair, rebuilding and hard surfacing of damaged, distorted or worn parts by welding were now accepted practice. Mild steel welded structures had the advantage in dredge construction on account of their resistance to breakage under heavy service conditions, the ease of their repair and the reduced cost for the limited quantities involved in dredges, which are normally "custom built." The welding designer was also able to dispose the metal to the best advantage, producing a component of comparable strength but of reduced dimensions and weight. Though mild steel resisted corrosion less than cast steel, the cheaper maintenance of the welded structure restored the balance.

The lecturer then touched on the inspection of welding and the use of regular tests, including X-rays, and went on to show a large number of extremely interesting slides illustrating the types of construction for which welding is specially advantageous. These slides showed some of the welding components for dredging craft, such as rudder posts, stern frames, winch parts, cylinders for winch

engines, engine soleplates, main engine columns, dipper buckets and arms. The lecturer in each instance explained why welding had been adopted and what were the advantages gained.

The discussion which followed raised many questions on such matters as heat treatment of components after welding, the lack of standard rolled steel sections in the fabrications shown, the stability of welded components and the use of Gamma rays for the examination of welds.

At the meeting on 2 November, Mr. E. V. Beatson presented a paper on the "Joining of Coated Metals." The paper, which was previously given to a joint meeting of the Institute and the Electro-depositors' Technical Society, is printed in the Journal of the latter body for March.

The lecture was illustrated by interesting examples of the jointing of coated materials, and actual specimens of the components shown on the slides were passed round for members to examine. In the ensuing discussion, Mr. Beatson was called upon to answer many questions, including several concerning the metallurgical condition at the interfaces of some of the joints which he had shown.

North Eastern-Tyneside.—The annual dinner of the Branch was held at the Grand Hotel, Newcastle-upon-Tyne, on Saturday, 19 November, the Branch Chairman, Mr. J. A. Dorrat, being in the Chair. There was a large attendance, approaching 200 members and guests, and speeches were drastically rationed, as is customary with this Branch. The Chairman of the Branch proposed the toast of the Institute, to which Mr. C. S. Milne, Vice-President, replied. A musical entertainment including some highly original and amusing conjuring followed, and the reluctance of visitors to leave the hotel was the best possible testimony of their enjoyment of the evening.

North London.—At a meeting held in the Polytechnic, Regent Street, on 19 January, Mr. C. A. Burton delivered a paper on "Developments in the Technique of Resistance Welding." Beginning with the basic principles of spot welding, the lecturer traced developments from the single spot weld up to series spot welding and multiple spot welding, and went on to speak of practical applications of multiple spot welding, illustrating his paper by slides and giving production times for comparison with similar articles produced on single spot welding machines. Portable spot welding development was discussed in some detail, especially in relation to its application to motor car body production.

The latest developments in light alloy spot and seam welding operating on the "three-phase" balanced load principle were explained with the help of slides illustrating the welding current wave form and actual machines.

The principles of projection welding were also explained and some account was given of the latest applications of this process, increasingly popular for the production of a very wide range of articles. The lecture closed with a description of seam welding equipment and the display of slides illustrating special high speed production applications, such as shock absorber components.

Sheffield.—The President of the Institute was unfortunately prevented by the strike on the Irish mail boats from attending the annual dinner of the Branch, held at the Royal Victoria Station Hotel, Sheffield, on Monday, 16 January. The attendance was again about 90, and members and guests spent a very enjoyable evening. The toast of the Institute was proposed by the Master Cutler (Mr. W. R. S. Stephenson), the Secretary of the Institute (Mr. G. Parsloe) replying in the absence of the President. Mr. F. Williams proposed the toast of the Branch, to which the Chairman, Mr. A. Robert Jenkins, J.P., replied. The Chairman, Mr. C. Cyril Hall, who is also the Branch President, proposed the toast of the Guests, and the response was made by the Hon. R. A. Balfour, President of the Sheffield Chamber of Commerce. As usual there was no other entertainment than speeches, but the speakers responded to the challenge to the satisfaction of their hearers.

Wolverhampton.—The lecturer on 16 November was Mr. E Fuchs of the Imperial Chemical Industries Ltd., Winnington, Cheshire, and the title of his paper "Safety in the Practice of Welding." A large audience included safety officers and other executives from engineering firms throughout the Branch area.

Mr. Fuchs divided his subject broadly under four main headings: (a) protection against light rays, hot metal and fumes; (b) provisions and precautions in establishing working conditions; (c) dangers associated with inflammable and explosive gases; (d) dangers associated with repair and site work.

There was a lively discussion, opened by Mr. W. R. Wrate, Assistant Sales Manager (Equipment) of the Quasi Arc Co. Many speakers quoted from their own experiences (some extremely unpleasant) in giving point to their remarks.

At the meeting on 14 December, the title of the paper "New Welders for Old" seemed to have a certain topical note belonging to the pantomime season, but the address, given by Mr. G. G. Musted, a member of the Branch, was concerned with a serious and important subject, the training of welders for industry. Mr. Musted, who has himself played a big part in the theoretical and practical training of new welders over a long period, traced the development of welding schools and arc welding classes in technical colleges, mentioning that one of the earliest, a three-year course begun in 1926 at the Liverpool Technical College, had been started by Mr. E. A. Atkins, M.Sc., some time President of the Institute and a Wolverhampton man.

The lecturer described five types of schools, namely: (1) the private or works school, where men were usually trained for specific types of work; (2) the Ministry of Labour or Government Training Centres; (3) the Technical Colleges or Institutes; (4) the industrial schools, generally conducted by the makers of welding equipment; (5) the Rural Industries Bureau.

Each of these had its special advantages and disadvantages, but Mr. Musted thought the private and industrial schools, which were strictly practical and had plenty of modern equipment, were preferable to others. He drew attention to a very excellent school in Paris, conducted by the French Institute of Welding, which provided a valuable course over a period of years, and really did train practical welders, who obtained certificates of some standing in industry.

Among the difficulties encountered by instructors were "bad habits" among their students, often caused by the type of work on which they had previously been engaged. For example, former painters tended to handle their electrodes with a brushing motion, and "leftward" welders could not easily change to "rightward technique."

The paper evoked a lively discussion, opened by Mr. A. R. Pegler, who also favoured industrial schools. Replying to Mr. J. R. Thomas, who asked how best to test a welding applicant quickly, Mr. Musted suggested that he should be given two butt welds to make, one of three or four runs with small gauge rods, the other with large diameter rods. The examiner should first unset the welding machine and let the applicant reset it himself, and he should watch the welder during the test (though without worrying him), noting the stance and the time taken, as well as the appearance of the finished welds. The welds should then be broken and the results noted.

Both Mr. S. H. Griffiths and Mr. E. Flintham thought that technical college courses at present laid too much emphasis on theory and allowed too little time for practice. Thus draughtsmen and technicians often found it easier to obtain a certificate than the real welder. The Institute must share the blame for this, because its membership regulations made it comparatively difficult for many excellent craftsmen welders to transfer from the class of Associate.

Mr. Musted agreed in general with this point of view, but mentioned that the new syllabuses for the City and Guilds courses laid more emphasis on the practical side and that students were encouraged more and more to express themselves by hand sketches in their written work, a point which Mr. Clark (South London Branch) confirmed.

Mr. D. Llewellyn emphatically disagreed with Mr. Flintham about the policy of the technical colleges, most of which, he thought, were doing excellent work in the training of welders. There was a good attendance and the vote of thanks accorded to Mr. Musted was heartily supported.

INSTITUTE OF WELDING MEETINGS

The following is a list of Institute of Welding meetings arranged for the months of March and April, 1950, so far as particulars are available at the time of going to press:—

1 Mar. **Manchester Branch**
"Tooling for Welding," by R. M. Watts.

2 Mar. **Eastern Counties Branch**
"The Control of Distortion," by R. G. Braithwaite, M.I.C.E. (at Ipswich).

2 Mar. **North Eastern, Tees-side Branch**
"Welded Structures," by S. M. Reisser, B.Sc., A.I.C.E., M.I. Struct.E.

7 Mar. **South Western Branch—Plymouth Section**
"Automatic Stud Welding," by C. C. Henderson.

9 Mar. **South London Branch**
"The Cost of Welding."

9 Mar. **Eastern Counties Branch**
"General Fabrication," by W. Dunn (at Norwich).

10 Mar. **Birmingham Branch**
"Cold Pressure Welding," by A. B. Sowter.

10 Mar. **South Western Branch**
"Can it be Welded?—Weldability as applied to the Metallic Arc Process," by E. J. Mitchell, B.Sc., M.I.M.

10 Mar. **East Midlands Branch**
Joint meeting with the Lincoln Engineering Society. "Sound Welds—a review of the examination and testing of welds," by J. F. Hinsley (at Lincoln).

14 Mar. **Liverpool Branch**
"Welding in the Coal Mining Industry," by James Rainford, M.I.Mech.E., M.I.M.E. (with film).

15 Mar. **Wolverhampton Branch**
"Can it be welded?—Weldability as applied to the Metallic Arc Process," by E. J. Mitchell, B.Sc., M.I.M.

16 Mar. **North Eastern—Tyneside Branch**
"Flame Cutting," by E. Seymour Semper, M.I.Mech.E.

20 Mar. **South London Branch**
Annual Dinner.

21 Mar. **Sheffield Branch**
"Metallurgy for Welders," by E. C. Rollason, Ph.D., M.Sc.

21 Mar. **South Western Branch**
"Automatic Welding," by H. J. Stretton (at the Canteen of Fielding & Platt Ltd., Gloucester).

22 Mar. **Manchester Branch**
Film show (at Preston).

22 Mar. **North London Branch**
"Application of Welding to Cold Rolled Steel," by W. McKenzie, M.Inst.R.A. (at Enfield).

24 Mar. **Wolverhampton Branch**
Fifth Annual Dinner and Ladies' Night.

28 Mar. **East Midlands Branch**
"The Control of Distortion in Arc Welding," by R. G. Braithwaite, M.I.C.E. (at Nottingham).

31 Mar. **Birmingham Branch**
Dance.

31 Mar. **East of Scotland Branch**
Lecture (no details available).

4 Apr. **East Midlands Branch**
Annual General Meeting (at Nottingham).

4 Apr. **Sheffield Branch**
Annual General Meeting.

6 Apr. **Portsmouth Branch**
Annual General Meeting.

12 Apr. **Manchester Branch**
Annual General Meeting and Film Show.

12 Apr. **Wolverhampton Branch**
Annual General Meeting and Film Show.

12 Apr. **West of Scotland Branch**
Annual General Meeting.

13 Apr. **South London Branch**
Annual General Meeting and "Inspection and Weldability Tests" by T. L. H. Butterfield, D.F.H., A.M.I.E.E.

13 Apr. **North Eastern—Tyneside Branch**
Paper by C. H. White.

13 Apr. **North London Branch**
Annual General Meeting and Film Show.

14 Apr. **South Western Branch**
Annual General Meeting and Film Show.

14 Apr. **Birmingham Branch**
Annual General Meeting and Film Show.

14 Apr. **East of Scotland Branch**
Annual General Meeting.

18 Apr. **Liverpool Branch**
Annual General Meeting and Film Show.

20 Apr. **North Eastern—Tees-side Branch**
Annual General Meeting and "The Use of Radiography in Weld Examination," by E. Blakeborough.

TWO NEW SECTIONS

It is the aim of the Council, as far as possible, to enable every member in the British Isles to enjoy the advantages of Branch membership, and suggestions for the formation of new Sections and Branches are constantly reaching head office. Two such ventures have been launched in the last few months.

The South London Branch has opened a section for the **Medway** towns, with a Section Committee composed of Mr. L. A. Lidstone (Chairman), Mr. A. E. Harbord (Secretary) and four other members. Two public meetings have already been held, the first on 18 October last, when Mr. J. Davenport, President of the Liverpool Branch, lectured on "A Welder's Angle on Ship Repairs." There was a good attendance, the Admiralty Superintendent of the Royal Dockyard being represented by Mr. L. C. Coombes, M.B.E., R.C.N.C., and the discussion ranged over a good number of practical points. The second meeting was on 21 November, when, after a lecture by Mr. L. L. Arundel on "Gas Cutting," the decision to form a Medway section was taken and the Section Committee was elected.

The Liverpool and Manchester Branches have collaborated to bring into being a section at **Preston**, intended to serve the needs of members in the North-Western corner of England, hitherto isolated. The opening meeting was held on 19 October, and the Chair was taken by Mr. George Davenport, who, the previous night, had been lecturing at Chatham. The lecturer on this occasion was Mr. Pridgeon, Chairman of the Liverpool Branch, whose subject was "Some Factors for Consideration on the Arc Welding of Steel." Over 70 members and visitors were present. The lecturer dealt with parent metals, electrodes and welding procedure, dividing parent metal into four groups, low carbon steels, medium carbon steels, high carbon steels and alloy steels. Under each group Mr. Pridgeon described the type of electrode, design of structures, distortion and residual stress, preparation and welding procedures and heat treatment necessary for the production of satisfactory welds. The lecture was illustrated with a number of well-chosen slides, and the author had to answer a wide variety of interesting questions from ten members of the audience in the ensuing discussion.

A second meeting, held on 18 January, was addressed by Mr. J. R. Ferguson on "Production Welding." This meeting was also very well attended and the organisers in the two Branches are well satisfied with the response to their efforts.

WELDING COSTS

Experts in welded fabrication, with experience gained among leading British firms in many fields of application—structures, shipbuilding, pressure vessels and power station installations, oil refinery equipment—discuss the vital question of welding costs. Their varied knowledge and experience will give every reader something to think about and act upon.

THE Autumn Meeting ended with a discussion on Welding Costs on the morning of Thursday, 27 October, 1949. In the absence of the President, the Chair was taken by the Vice-President, Mr. C. S. Milne, who expressed thanks to Mr. Bondy for undertaking to open the discussion at very short notice, owing to the illness of Mr. H. B. Fergusson, the speaker announced on the programme.

Mr. O. Bondy said he felt sure it was not because he could claim to know anything about the subject of welding costs that he had been asked to open this discussion. Perhaps it was because it was felt that he had no axe to grind and that he could judge impartially in comparing welding costs with the cost of riveted and other structures. As a structural engineer he was just as happy using a riveted structure as he was using a welded structure, and if neither of these were satisfactory he would be happier still using reinforced concrete. Therefore, his remarks could be taken as the views of an observer who was independent in judging the prospects and possibilities of welding.

Those who had attended the meeting on the previous evening might have noticed that again and again the discussion, and the paper itself, dealt with the question of costs, and that was quite natural. After all, the chances and prospects of welding in any field of the metal working industries had to be judged finally on the possibility of selling the products and there was not much chance of selling even a good product if it could not compete in cost.

The subject of welding costs was almost an ideal one for discussion, because over the last fifteen years he had never found that two experts could agree on it. It could be discussed from many angles and the results would vary not only in accordance with the views held by those who discussed the subject, but also in accordance with market conditions and circumstances, which were bound to vary from time to time. It would be remembered that there was a tremendous shortage of steel a few years ago, but the position seemed to be a good deal easier now. But the shortage of labour also decisively affected a comparison of costs. Moreover, there was no absolute standard by which to compare the costs of different types of construction. The estimator had a most difficult task to perform. Having had to do this sort of thing for several years with one of the big steelwork manufacturers he knew that it was usual to allow a wide margin to play with, so that if the firm desired to get an order they could get it by cutting down prices here and there in the raw material and perhaps devoting a little more time to refinements of design and also in the workshop itself.

Importance of Overheads

Naturally, the wide margin was mainly provided by the factory overheads, and this item, which had to be added to the other expenses, was most welcome to the estimator. It might be argued that every job should carry the same percentage of overheads, 80 per cent., 100 per cent., 150 per cent., or even 250 per cent., on the cost of labour, but that was a question of argument. It might vary from job to job and it would certainly vary in accordance with the degree of efficiency in works organisation and workshop management.

It was a well-known fact that total costs were built up, in the main, from the following four factors: (1) Cost of raw materials, (2) cost of workshop operations, (3) the cost of shipping, loading, unloading, and (4) overheads. The workshop operations naturally included preparation assembly, jigging and welding cost, but welding was only one small section of the total costs for the final products. Also, if he might suggest it for the purpose of this discussion, in talking of welding costs it must not be overlooked that even the cost of the steel part of the finished product need not represent the total cost. Not every product consisted of steel or metal only. In steel structures the steelwork was only a proportion of the total cost. In a so-called civil engineering structure the steelwork itself might be a minor item and the question of whether the steelwork should be welded or not might affect those in charge to such a degree as might sometimes be anticipated. The saving in weight of steel, too, always a most important matter, was not necessarily the decisive factor. He would quote two cases to illustrate the extreme possibilities. In aircraft design they did not worry about labour costs, but they were very much concerned, and decisively concerned, in cutting down the weight of the finished product to the absolute minimum. The position was entirely different in the case of steelwork construction or with plate or boiler work. But the other extreme case was where the weight of steel might be anything, because the raw material cost so little as, for instance, where scrap materials were used such as old railway rails and the like. Some quite good structures had been built with old railway rails by welding. It was a question not of cutting down the weight but of cutting down the labour costs to the minimum. In other words, using more steel might be the more economic solution in some cases.

He had a feeling that these few words of introduction should be concluded by stating that they represented a purely personal opinion. If the welded job did not, in the end, show itself capable of competing with its competitors and come out cheaper, then something must be wrong either with the design or the manufacture or perhaps something else. That would be left to those present to discuss and, perhaps, to decide.

During a visit to Switzerland a few weeks earlier, some Swiss colleagues had shown him some welded steelwork in course of erection, and they were quite impressive structures. One of them was a 250 ft. span aerodrome hangar. When he asked whether they were using any riveted work, the chief engineer of one of the biggest steelwork manufacturers in Switzerland looked rather puzzled and could not understand the question. Apparently they had given up riveting some years before and would not dream of going back to it. It was common knowledge that the Swiss were extremely careful in cutting down costs to the absolute minimum and there was a good deal of competition among first-class designers. At the same time, it was not only a question of cost—and this applied especially to Great Britain where export trade was of decisive importance. Small differences in cost of the final product alone should not decide the issue as between different tenders. It was essential to bear in mind that quality would, in the last resort, decide the case. In the long run, quality would decide whether we should be able to get and keep export markets or not. Differences of cost would be forgotten, but the building or structure or whatever it was would still stand for those who came after us and they would judge and criticise on the basis of quality and performance.

As a last remark, Mr. Bondy said he felt the Institute of Welding had a mission to fulfil more in these days than in days gone by. Many of those present knew that the economic struggle ahead would be of vital importance. That knowledge came from previous experience. It was now a question of economic life or starvation.

The urge to better and increase production had been put forward so often that we were getting a little tired of it. However, an excellent tool, perhaps one of the best tools of modern times, had been given to them and it must be used to the very best advantage.

The Chairman, calling upon Mr. Burford, said that as assistant to Mr. Fergusson he would be able to put forward the arguments Mr. Fergusson would have used if he had not been ill.

Mr. E. F. Burford (Messrs. G. A. Harvey & Co. (London) Ltd.) said he wished first of all to present some notes which Mr. Fergusson had put together for this meeting and at the same time to express Mr. Fergusson's regret that he had been prevented from opening the discussion.

Mr. Fergusson's notes read as follows:—

In a large shop where a hundred or more welders may be employed on all types of weldments, it is essential, not only to obtain the most economical results, but also to enable the Estimating Department accurately to forecast the cost of all the welding to be done to complete any one job. This requires co-ordinated effort in the design stage, reduction in shop costs, agreed piecework rates for welders, training of welders, and laboratory control. The saving of a considerable amount of welding can be made in the design stage by folding of plates, for instance, into box sections, the use of rolled sections, egg box construction, bent U plates for stiffeners, large diameter, hollow shafting made from rolled plate with a longitudinal weld, butt welds being adopted in preference, where possible, to fillet welds. In many cases the design should admit of the work being broken into sub-assemblies which can be separately stress-relieved and then each sub-assembly joined together for a final stress-relief of the whole job. This method avoids troubles and delays through distortion.

The draughtsmen must avoid inaccessible parts requiring welding in cramped positions, and the placing of a number of the welded joints close together.

The adoption of tubular construction is often advisable for certain structures.

Flash butt welding of angle rings, etc., often results in considerable savings.

There are occasions where the use of stud welding machines and even plug welding will make considerable reductions in welding costs.

Where several articles of the same type have to be made efficient welding jigs should be designed and accompany the drawings for the job itself which are sent down to the shops.

The draughtsman can often save on complicated small sub-assemblies by having these made as steel castings.

The following are among tools and devices useful for reducing shop costs:—the provision in the shops of bending brakes; rotators for welding cylindrical work; positioning machines, enabling all welding to be done downhand, and possibly of even more importance, releasing overhead cranes for other work; the use of automatic welding heads; provision of slotted cast-iron floors, and the installation at convenient places of drying cabinets for electrodes.

Schedule of Piecework Rates

Probably the most important saving in welding cost is achieved by having a schedule of piecework rates. This should be most carefully drawn up and must be agreed to, in writing, between the management and the shop stewards representing the welders.

Such a schedule must include almost every type of welding that can be visualised, and also the rates for chipping and grinding-back of the proud metal on welds, which is always necessary if the welds have to be X-rayed.

Broadly speaking, these rates must cover the price per foot for different thicknesses of metal for butt welds in mild steel, stainless steel and various alloy steels and clad steels for Class I, II and III welds, and a similar list of rates should be got out for fillet welds.

Special rates will have to be agreed for positional work, such, for instance, as vertical and overhead welding; these will, of necessity, be higher than those in operation for downhand welding.

Special rates apply for unusual work, such as the welding and making-up of large segmental dished ends. For a slope of not more than 25 deg. we add 20 per cent.; 26 deg. to 45 deg., 25 per cent.; and 46 deg. to 75 deg., 35 per cent.

Special rates must also be agreed for the welding-on of fitments, such as standpipes of various diameters, including compensating rings, etc.

Clad material rates are generally fixed at a price proportional to the ratio of mild steel to clad material.

An additional allowance must be agreed where pre-heating by gas or blowpipe is necessary before welding, as, for instance, in the welding of alloy steels.

Any inexperienced welder, who cannot earn his minimum piecework bonus on a job is put on day rate. Basic rates for welders will naturally vary. Those capable of doing X-rayed Class I welding, of course, get the highest basic rate.

All welders should be tested before they are taken on. It is important that all welders, except those on X-rayed work, should have their welding tested periodically by welding certain test samples of various thicknesses of plate, including butt and fillet welds in the downhand and vertical positions, all the test samples being X-rayed, and the samples from each welder being judged by an independent expert who does not know which welder did the work. The judge points out, not only the faults in the welds, but the reason for them, and the methods of obviating them.

Where a large number of welders is employed it is essential that there should be a welding school at the works, where newcomers can have training, especially in the welding of new types of metals, such as some of the stainless steels and clad material, before they are put on to the actual production welding of these more difficult jobs.

With a good many types of alloy steels, clad materials, and non-ferrous metals to be welded nowadays, it is essential before any such work is tackled, that the problem should be studied by the laboratory under the supervision of a capable metallurgist. The laboratory staff should have their own welding facilities, so they can experiment by doing the welding themselves and studying the best electrodes to use, as well as the welding procedure, before work is started in the shops.

Mr. Burford then displayed a chart prepared for Mr. Fergusson which gave an indication of how the piecework rates paid to the welders would vary with the different thicknesses of material and different types of material welded to Class I, II and III standards.

Mr. Burford then made some remarks on his own account, as follows:—

I am assuming that this discussion on Welding Costs arises from the continual complaint that when a job is changed over from riveted to welded design, the cost of the latter is higher than the former, although the general idea of welding is that it cuts out certain manufacturing operations; it is generally easier to connect pieces together by welding than by riveting, and consequently the cost of a welded job should be cheaper.

What the Customer Wants

Being mainly concerned in the design of welded fabrications, mostly pressure vessels, but also storage tanks of one description or another, and machine parts such as press frames, I agree that a considerable amount of welding can be saved in the design stage, but we as manufacturers, in very many cases, are supplied with drawings by our customers, more particularly on special work, where the designs are fairly fully detailed, and quite a number of our special customers have their own ideas as to the amount of welding which should be put on a job.

Sometimes I criticise the amount of welding, but am invariably told by the customers that this is what they want. Maybe we have already quoted for the job to their design, and consequently have to give them what is shown, and also suffer the consequent distortion troubles. Even when we have a free hand for very low stressed parts, there is a certain amount of welding which has to be done so as not to give the idea that the job is being skimped, but such welding is often far in excess of actual strength requirements.

Another factor which has to be considered is corrosion. Often

in tank work it is necessary to use full welding on stiffeners, although we know that stretch welding, or even spot welding, if practicable, would be quite good enough.

In riveted work, meeting surfaces could be painted, and wide pitch riveting used, but in welding such treatment of the meeting surfaces is impossible and we have no alternative but to use full welding, which naturally puts up the price.

Mention has been made of the folding of plates into box sections, and I am indebted to Mr. Semper for the maxim he gave us some while ago, when he said "*fold more and weld less.*" It is certainly very true, and its adoption by industry is recommended.

It has also been said that butt welds should be adopted in preference, where possible, to fillet welds. Certainly the butt weld is the strongest form of weld, but personally I would not give it as a hard and fast rule, that it is the best type of weld for all purposes. In using lapped joints with fillet welds, the preparation is much simpler, the lap takes up irregularities in preparation and the size and nature of the welds may be reduced, whereas with butt welds, the plate thickness governs the size of the weld.

Inspection Requirements

Another important factor applying to welded pressure vessel construction, is the rigid requirements of Inspecting Authorities such as the Boiler Insurance Companies. I am not going to decry the very valuable work done by them in insisting on and maintaining a high standard of welding for this class of product, but considering that nearly every pressure vessel made to-day is subject to inspection during manufacture and approval by one or other of the insurance companies—a considerable amount of time and additional work is taken up in satisfying their requirements, which in many cases appear to be too rigid, if, as we think, we have reached a high standard of welding. Even on a Class II job, not subject to X-ray examination, where the joint efficiency is rated as 67 to 77 per cent., which for 26-ton material is equivalent to working stresses of 9,700 and 11,200 lbs. per sq. in., six independent inspections are required on each such vessel, starting with an examination of the plates at the plate-maker's works and including examinations for and after welding and the various tests.

The rules state that two test plates shall be attached at each end of each longitudinal seam, although in a long vessel, having a number of belts, this rule is somewhat relaxed. Nevertheless a considerable amount of time and money is spent in making and preparing required test specimens, and although the surveyors do their best to work in conjunction with the manufacturer's requirements, time is lost and money is spent in picking up and dropping the jobs. The Class I tests are naturally more exacting, which is only to be expected.

An additional expense is the stress relieving of jobs, and it is as well to look back a few years and consider that in comparable riveted jobs a double riveted lapped joint or a simple butt strapped joint would give the same joint efficiency. The joint efficiency was calculated, without having the prepared tests for each individual job, and of course, there was no question of stress relieving.

It does appear to me that more confidence should be placed in the fabricators. Most works of any size test and grade their welders periodically, and if they are doing Class I work, then they are tested at very frequent intervals.

In comparison, the American A.S.M.E. Code for Unfired Pressure Vessels specifies that a pressure vessel shall be inspected at least twice by an approved inspector. A data sheet has to be filled out and signed, this is clerical work. Test requirements are for one coupon plate on *one* end of *one* longitudinal joint of each vessel, the test specimens even for a Class I job being only equivalent to a British Class II job.

If something could be done to reduce the number and extent of tests, and if the insurance companies got together and appointed one man to look after a big company's work, then I consider the final cost of a job could be reduced, and after all it is the final cost that we are looking at.

In manufacture, accurate edge preparation and assembling of parts to be welded play an important part. There has been a considerable advance in the last few years in plate edge preparation by gas cutting, and particularly in correct preparation necessary with some forms of automatic welding. Manipulators and rotators are necessary as part of the works equipment for handling jobs, and reduce cranage waiting time.

Mr. J. R. Thomas (Messrs. John Thompson Ltd.) remarked that Mr. Burford had covered the subject very fully, and that he agreed implicitly with many of the points he had made, in particular with his remarks on the requirements for the various codes covering Class I and Class II design and welding, where there exist many anomalies.

A case he could cite from experience was of a welded Lancashire boiler, a product which was normally riveted. A very complete series of tests were carried out on the vessel and comparison was made with the normal riveted product. Much valuable knowledge was gained and it was obvious that there was considerable improvement in many ways, particularly in the regular behaviour throughout various fluctuations of loading condition, opening up possibilities of increased pressures or thinner plates. Also, due to the welded construction, there was an economy in finished weight of 4 tons or 16 per cent.

Unfortunately, the requirement of full radiographic inspection for all seams, longitudinal and circumferential, together with other inspection requirements, so increased the cost that a welded boiler could not be produced at the price of the riveted type. There were other cases where the cost of rigid inspection requirements retarded development and progress, so delaying the many benefits which welded design could give.

He agreed with Mr. Fergusson's point on the provision of heated storage cabinets for electrodes, placed handy to the welding, so that the electrodes were always available to the welder in the best possible condition. This prevented wastage of electrodes. The practice of having partly used cartons of electrodes around the shops should be frowned upon.

He also agreed with Mr. Burford that welders working on Class I work, for which radiographic inspection was required, were thoroughly tested on every inch of weld they made and that no other tests should be necessary. Any falling off in a man's work was immediately noticed and the operator should be put back for a period of training or sent on to other work.

Estimating Weld Time

Referring to other classes of work, Mr. Thomas said it was his province to act in an advisory capacity to the various companies in the Thompson group, whose welded products varied from steel windows, industrial flooring, motor car chassis, structural work, and pipe work, etc., to pressure vessels. The problem had been to lay down a method for estimation of weld times which could be used throughout these various classes of work. The method arrived at was to produce charts giving a wealth of information, such as the best method of making the weld, electrode size, amperage, deposition length per electrode, etc., the quantities of electrode required per foot of completed weld and the melting rate, that is the welding potential per foot of weld. It was the latter figure for which variation must be made to suit the various classes of work, and the answer was for each department to arrive at an efficiency figure to suit their product. This would vary considerably for different classes of work. For instance, one shop might arrive at an efficiency figure of 42 per cent., that is the weld-potential figure was taken as 42 per cent. of the allotted welding time per foot, or the time allowed for welding, de-slagging and for contingency. Analysis of the welding time showed that cleaning and other factors accounted for the greater part of the time, and whereas the potential time was a constant, considerable savings might be made in the other factors by the use of jigs, fixtures and mechanical aids for cleaning, such as light pneumatic chipping hammers, rotary wire brushes, etc., in addition to the normal hand tools.

In the preparation of work for welding, there was no doubt that oxygen cutting had many advantages and very good results, involving considerable savings, had been achieved in cases where oxygen cutting apparatus had been developed to meet special circumstances. In this connection, he appealed for the co-operation of firms in the oxygen cutting field to help in the development of special machines. There was a big field undeveloped here, as with

oxygen cutting one had a powerful cutting tool, yet with no tool reaction, which made possible light, portable equipment, capable of heavy and accurate work.

Finally, he would emphasise the use of mechanical aids in all stages of welding-jigs, manipulators, automatic and semi-automatic methods, pneumatic and electric hand tools for weld cleaning. It was here that the greatest economies would be found in the welding operation. Too often one saw welders chipping away at slag with the tang of an old file, thus wasting far more time than had been required to deposit the weld.

Mr. B. W. Silverwood said that, after having listened with close interest to the discussion thus far, he nursed a suspicion that some important issues had been completely ignored; he then dealt with the four following items: Quality and strength of the supervision, electrode selection, electrode usage, and co-operation with other departments.

On the question of adequate and fully-trained supervision of welded work, Mr. Silverwood said that he had very bitter memories; he readily gave due credit to a large force of conscientious welding foremen and supervisors, who were at all times doing their best to discharge their onerous duties, very often in the face of serious opposition from a variety of sources.

A direct and fully-justified accusation could, however, be levelled against a very large number of so-called welding foremen, inspectors and supervisors, who had no more knowledge of, and due appreciation of, welding than a street-corner newsvendor.

It would be readily conceded that many men in charge of welding work had not obtained their responsible position on merit or experience, and were therefore not entitled to the post.

Skilled Supervision Needed

In many cases the supervisory staff was drawn from among the ranks of caulkers, riveters and platers; in one case the foreman welder had been a shipyard painter. The cynically minded might point out that the physical motions involved in painting and welding, as undertaken in certain establishments, are not entirely dissimilar!

Mr. Silverwood insisted that any man who held a supervisory post in welding should have a thoroughly good grounding in the practical application of the art, and whenever possible should be carefully selected from among the operative welders in the establishment.

The quality and strength of the supervision was indeed very closely related to the "Cost of Welding," as only by the employment of the right type of man could the costly mistakes of apathy, ignorance, mis-direction and traditional hostility be avoided.

Choosing and Using Electrodes

There was a tendency, when selecting electrodes, to concentrate too much upon the price, and too little upon many other important factors. This was to be deplored, especially because the mechanical properties of the deposited weld-metal were very often ignored.

Moreover, welding electrodes of different makes, but with practically the same mechanical properties might, in other respects, show outstanding differences which had a considerable bearing upon the ultimate cost-price of the completed work.

The only fair, and satisfactory, yard-stick of comparison between electrodes was that which allowed for all the factors which collectively determine the quality and the price of welding, among them the resultant mechanical properties, the "burn-off" rate (this directly affected the time needed to complete any welding job, and hence the costs), and the welding current consumed.

If the prospective consumer decided, through lack of experience, or through ill advice, to buy an inferior quality product because of low-price attraction, then he must also be content to accept a lower speed of deposition (this brings in its train a host of labour troubles, due to the inability of the operators to earn the maximum piece-work rates), a higher current consumption, bad solubility of the slag (giving rise to a succession of welding defects, which had to be removed before re-welding), high wastage of electrode material through excessive spluttering. It was quite evident that, in the ultimate result, the so-called "cheap" electrodes would, very probably, cost much more than the product of first quality. The cost of welding electrodes, even of the very best quality obtainable, was an insignificant proportion of the total cost of any arc-welded product, so that the only possible moral was to steer clear of a sacrifice of quality in order to effect a supposed saving in direct outlay.

Wastage of electrodes was still widely prevalent over the whole of the country. It was a common experience to find unopened boxes of welding electrodes dumped into the nearest dark corner of the establishment; in shipyards throwing boxes of electrodes over the ship's side seemed to be a pastime.

Requiring stub-ends to be returned to the store before the issue of a fresh supply was of little avail, because it was comparatively simple to have on hand an adequate supply of stub-ends by the use of the hack-saw.

The question of efficient electrode usage was related to the strentgh and the quality of the supervision; a properly experienced welding foreman or supervisor took pride in the efficient organisation of his department and the fact that he had been "through the mill" himself, and, therefore, "knew all the tricks," commanded the respect of employers and operators. Electrode wastage went down as the quality and experience of the supervision went up.

Co-operation among Departments

Yet another important factor in welding costs was co-operation with the other departments directly, or indirectly, associated with the welding operation.

Were they, in all cases, receiving undivided support from the plating department, or the riveting department, or the caulking department? How many thousands of man-hours were wasted daily because of needless delays occasioned by a complete absence of co-operation on the part of the associated departments?

For example, during the construction of a 10,000-ton ship the welding department received a request from the plating department to weld the 110 feet-long bilge keel to the shell.

Upon inspection of the job, the welding foreman discovered that one end of this bilge-keel was ¾ in. away from the ship's side. When the foreman plater was approached with a request to rectify the defect, he suggested that the gap could be very quickly filled up with old electrode ends and some long thin bolts, and even offered the help of a small boy to find some suitable bits and pieces.

Eventually, the Classification Society's inspector was surreptitiously called in to the yard by the foreman welder. The removal of the offending plate and the substitution of the correct one occupied three men for four days.

Close attention to the matters raised in all of the foregoing remarks could bring about considerable reductions in the costs of welding. The welding industry should not be expected to swallow, rather humbly, the accusations made against welding by people who did not know much about it, did not like it, but who still made claims that it was much more expensive than riveting.

The British welding industry prided itself on being right in the forefront of progress in welding matters; the most effective use of every means possible to keep welding costs at an economic level was one of the most powerful agents to which it could resort in retaining that enviable position.

Mr. George H. Smith (Messrs. Boulton & Paul Ltd.) said he had not intended to speak in this discussion, but he had been tempted to do so after listening to previous speakers. The whole object of this meeting was to consider costs, but nobody had mentioned what, in his opinion as a structural engineer, affected more than anything else the cost of welding, viz., the provision of adequate sections.

Sections for Welding

He did not know whether our rolling mills were really setting themselves out to consider this problem. One of the factors causing high cost of welding in structural engineering was that they were working with heavier sections than were necessary for welding, sections designed for the use of bolts and rivets. He felt that until the mills really got down to considering the sections that he had seen continental firms producing, the welding industry would be faced with higher costs and wasteful materials. Therefore, he asked for some information as to whether the laboratories of the various mills in this country were studying this important factor in the cost of welding.

Another thing that had been mentioned by previous speakers was the use of cast iron slotted frames, in other words, like the

slabs of shipyards which he was familiar with in his early days. In his opinion, however, although they were admirable for that job, the large size and inconvenience of handling them put them out of reckoning for many firms. The capital expenditure involved was considerable and he felt that something lighter should be made available, preferably with a machined surface arranged so as to be more easily assembled in small workshops. He would very much like to know whether such a thing was obtainable, and felt sure that his firm and others would welcome them if they were not so expensive as the heavy shipyard type.

Mention had also been made of laboratories in such an elaborate way, that he could not see the small firm being able to afford such an addition to their establishment. When the proprietor of a small firm heard of the elaborate testing of materials he was rather inclined to be "choked off" welding altogether. Personally, he thought the word "laboratory" was a rather high falutin' term for what was necessary for the adequate testing of a weld on the jobs which the majority of small firms came across.

Another factor regarding the cost of a weld was its size, which had also been referred to by a previous speaker. It was rather "thick" when a designer regarded a ¼-in. fillet weld as good enough but for safety reasons put a 5/16 in. weld on the drawing. Then the welder thought it would be better to make it ⅜-in. and so it went on. He had seen that done repeatedly, and the same thing applied to larger size welds. There would be a distinct saving on welded jobs if the design were carefully followed and there were strict adherence to the figures considered right in the first place.

Dangers in Bending

The folding or bending of plates had been mentioned. Folding was all very well provided it was not over-done to the extent of getting too sharp bends. He had seen many jobs which, from the economic point of view, were very good, but if the condition of the plate at the particular bend or fold were examined minutely, it would be found that instead of having 100 per cent. strength at the corner, it was reduced by about 25 per cent. by minute fracture for about two-fifths of the depth of the material. Folding was all right if the rules laid down by the various manufacturers of steel plates were followed. Unfortunately, the general tendency in the shop was that the sharper the bend the better the job, which was quite wrong.

Inspection was another big item of unnecessary cost, probably because people were a little too afraid of welding. They thought they ought to have someone to come and look at the job and inspection was then carried out, as had already been mentioned, by inspectors and supervisors who knew very little about welding. His own experience of inspectors was that the more welding that could be done on the site, and the higher up it was, the better, for the job was then less subject to inspection, which only went to prove that the inspectors did not know where to look for a bad weld. They spent too much time on the ground.

The wastage of electrodes was a serious matter. His experience was that every welder liked to be his own storekeeper, but that the best system was to make the welder go to the foreman for a slip for every packet of electrodes that was wanted. There had been colossal waste, but when that system was introduced in his own case the consumption of electrodes went down by 50 per cent. There was a round-up in the shops and packets of electrodes were found in the most unlikely places. The wastage of electrodes on the outside sites was also a colossal matter, and if one climbed about the job they were found in the most inaccessible places. Finally, Mr. Smith said the most important point he wished to bring forward was the lack of adequate sections for use in structural steel welding.

Mr. W. Heigh (Messrs. Babcock & Wilcox Ltd.) said that on this subject it was inevitable that they should find themselves covering much old ground and discussing the same difficulties in practical welding as had always been experienced and had been so often discussed. He would like to broaden the field. After all, many of the faults in men and organisation complained of were just common experience and were capable of being eliminated by good management. If we wanted good welding and good behaviour by welders we must ask for them and insist on them.

During the war, certain discussions in the shipbuilding industry turned frequently to this question. Those concerned were men of large experience in handling labour—and in welding. Agreement then and experience since had proved that good quality welding and economy in labour, material, weld metal and electrodes and in most of the things they had been discussing were largely, if not altogether, a matter of purposeful control. In his own experience, insistence on quality work of all kinds was the most effective and the most congenial discipline and produced automatic economy.

Courses on Welding Design

But economy in a welded job was seldom merely a question of the cost of actual welding. Usually there were larger factors, as, for instance, design. In this connection he would like to make a suggestion. During the war, largely on the inspiration of the Institute the Admiralty arranged very successful courses on welding for senior executives in the shipyards and this was followed, immediately after the war, by courses arranged by the Clyde Shipbuilders' Association for the senior ship draughtsmen on Clydeside. The lecturers were experts from all over the country, each covering a small part that was not too much of an intrusion into his very busy life. Also, the mature experience of the students enriched the study of the subject in discussion. While the instruction of the young men of the industry in design and practice in welding was certainly good, necessary and long overdue, the more experienced men must be well informed or, as in structures, welding practice would be bound to lag behind the knowledge available, because the older men controlled policy. It was suggested, therefore, that the Institute should take the initiative in introducing courses that would suit all draughtsmen—say, short intensive courses of lectures based on the British Standards Specifications and Codes of Practice now in process of publication, possibly with lectures on certain researches in which the results were available for immediate application to design and the job; these would probably constitute an excellent syllabus for this particular purpose. It was likely that employers' associations and the other technical institutions would co-operate, and the education departments grant facilities, as those other competent authorities and associations did during and just after the war.

But another aspect of manufacturing economy should be considered, because we had to face the problem as engineers, not merely as welders. Piece-accuracy was required so that composite structures would come together at the assembly stage without forcing, without expensive fitting and trimming and without packing with welding. This was not a theoretical ideal, but had been in practice, and progessively improved upon, for many years, in all line-production manufacturing methods—mess, continuous and the like—nor was it untried in more general work. Consider what would happen in any production line if pieces were habitually inaccurate and had to be continually withdrawn for correction. Economy would disappear; costs would actually multiply. The pursuit of piece-accuracy, a sustained pursuit in all the details of dimension and manufacture, would produce substantial economies, immediately, and continue to show progressive profit for years. He would not be surprised to hear of workshops starting from quite a good level of efficiency, yet doubling the output per man by such means. He knew of one case in which the output of 550 men had been trebled and of certain other types of production in which the effect was likely to be at least as great.

First-Time-Rightness

A third approach to economy was simply first-time-rightness. Quality had already been mentioned, and undoubtedly good quality welds could be the most economical possible. But if, speaking more broadly, in all trades—"sheltered" and "competitive"—the managements, technicians and the men with superior skill and goodwill could infuse all their own work and the work of those for whom they were responsible with first-time rightness (in all operations) a miraculous transformation would take place in the quantity and quality of British productions of all kinds. We had a birthright of technical and crafts skill and industrial achievement on which to build and of which the ideal was surely the logical consequence. This was a job for every workshop, every executive and, finally, for every man. He believed that his own experience showed that most operators were vulnerable to the reproach that due to their carelessness another man had had to do

their work over again. But, to be effective, this reproach must be "brought home."

A fourth large practical principle seemed sometimes to have been forgotten. Complaints about costly welded work had been frequent. Was the reason difficult to find? It had been referred to more than once in this discussion already. The traditions of riveted work, useful and economical in that work, were being carried over and added into the routine of welding manufacture. Welding had so far acquired no traditions; for this, time and experience were scarcely ripe. One cause of extra cost, more important than might be expected, was merely unsuitable shop routing (too much handling) of composite pieces, especially when some of these were joined by riveting or bolting. It was doubtful if expensive plant would contribute nearly so much to economy in any job as careful, thoughtful elimination of wasteful movement, labour and material —at small cost.

As an example, one job might be quoted. It had been estimated for when the workshops concerned were comparatively slack. The price and method of manufacture were believed to be keen and economical; the manufacturing routine was well established. When the job matured, these shops were so busy on more normal work that neither platers nor welders could be spared for the job. Instead of six weeks' work for six platers in the preparatory stages, the relevant operations had to be performed without platers if at all possible. Other economies in skilled labour had also to be found to the maximum extent possible. Marking had been eliminated by very inexpensive tools and other operations had been combed to save labour. Movement particularly had been cut to the minimum. The nett result was nearly 25 per cent. saving of shop labour, although the job at the original price could not have been described as expensive in comparison with any possible alternative.

Not new expensive machinery, not new operators, not new theories, but just the progressive painstaking pursuit, now as hitherto, of piece-accuracy, first-time-rightness and the competent engineer's adjustment of his organisation to suit the changing needs of each new development in practice and design—in which each man, from top to bottom, had his own part, but in which leaders must lead. That seemed to him to be the way to economy in welded constructions, rapidly becoming all constructions, and to be to-day's task for the engineer. In his opinion the first profit would be immediately apparent and substantial.

Mr. E. Flintham (The Quasi-Arc Co. Ltd.) said he wished to join issue with Mr. Silverwood, because some of the matters he had raised were matters of good housekeeping, and surely the members of the Institute represented firms which should exercise good housekeeping. Indeed, he thought the matter went much farther back than that. It was necessary so to educate welding designers that they would produce designs which would give competitive prices for welded work as against riveted work. Prospects for welding were almost killed from the start because designers estimated the cost for welding work as higher than that for the riveted job and the welding industry never got a real chance. That was the big trouble; and it was the design that made the cost of welding work higher than that for riveted work. He felt it was up to the Institute to issue handbooks and information on the design side, so that designs could be evolved which lent themselves to cheaper construction.

They must be prepared to adopt welded structures even if they were more costly, because of the æsthetic value of welded structures and because of maintenance costs. This point was brought home by a comparison of some of the very good welded structures at continental railway stations with the riveted structures at certain British stations which appalled him.

Emphasising the importance of quality, he said that quality work would bring repeat orders, and therefore quality must be insisted upon. The all too-frequent examples of bad welding in ships and structures discouraged engineers when they thought of adopting welded designs. Welding craftsmanship must be considerably improved; welding was a wonderful tool and must be used to the best advantage.

Mr. Bartlett C. Little, agreeing with the previous speaker, said that if they designed for welding, then a welded job would be obtained, and he did not believe it would be more expensive than riveting. There was proof of that in the fact that there were firms with the books filled with orders for welded cranes, conveyors and welded construction generally. If welding work was given out to firms who did not know anything about riveting, then a welded job would be obtained which would at least be as cheap as a riveted one. Therefore, a start must be made with the designer and the drawing office, to ensure that designs were for welded construction.

Mr. A. G. Thompson (The Quasi-Arc Co. Ltd.) remarked that the Prime Minister had recently said, in effect, that if the standard of the average in industry was as good as the best, we should be out of all our troubles, and this was true for any industry.

Therefore, his remarks would be along these lines with regard to the reduction of costs in the welding industry, because he felt that the quickest overall improvement could be made in the large number of smaller constructional or fabricating firms.

There was no doubt that the design aspect was exceedingly important and design was often affected by controlling authorities. Many small structures such as factory buildings, roof trusses, and so on, were subject to control by local authorities, who (he thought) would frankly admit that they were not fully conversant with welded structures and the full implications of welding on the design of the various component parts. He knew of instances where the authority had increased the size of members to more than they would have required for the equivalent riveted structure. It was obvious that by eliminating rivet holes on tension members, etc., these members could be lighter. A case had come to his attention concerning a small angle iron structure not carrying heavy loads, where the local authority had asked for radiographic tests! Surely some general basis of design, such as B.S.S.449, 1948, should be generally acceptable, without the need for convincing authorities of the dependability of welding in each individual instance. The designer, too, in many places was handicapped by not being sure that he would get what he asked for. If he asked for a ¾-in. rivet, he got it; but if he asked for a ¼-in. fillet, he was not sure he would get it. He might get 3/16 or 5/16 of an inch leg length, unless the supervision was very good. One way in which considerable cost could be saved was for every designer or shop to specify how the weld should be made. That was a very simple question of mathematics; a number of people had done it, and procedure tables were available from various sources. If a ¼-in. fillet was wanted, the welder should be told how to do it, and if these instructions were stated on all drawings or the procedure laid down in the shops, this alone would lead to considerable savings throughout the country.

Size of Welds

Another point was the size of welds. In many cases, especially with fabrications, the size of the weld tended to be too large and that brought a lot of troubles in its train. He had come across a case where it had been possible to use welds half the size of those originally specified, with the result that the amount of weld metal to be used was reduced to quarter of the original.

With a plate structure with stiffeners welded on, all sorts of difficulties might occur. If the vertical webs were made very deep in relation to the plate, there was a less economic construction than if they were made shallow because of the asymmetrical form, which gave rise to very high stresses on the outside fibres, using the accepted basis of design.

Actually, the job represented in this sketch failed originally because there was too much weld metal deposited on too many small pieces of plate and there was resort to pre-heating, special electrodes, etc. Thus there was an optimum weld size for most jobs and the strength and dependability of the construction would be reduced by further increasing this size. It was also important that this optimum size of weld should be deposited in the quickest and easiest manner. Large gauge electrodes should be used where possible to reduce any difficulties due to cracking and to ensure that the metal was put down in the quickest time and in the cheapest way.

Mr. H. G. Hope said he had anticipated when he came to this meeting that he would hear some suggestions whereby new life would be given to welded work, but most of what he had heard was that welding was more costly than riveting. Personally, however, he did not think that was so in general structural work. He

thought their biggest trouble was conservatism on the part of people who did not want to change. In his small works there was one shop which had been arranged for welding, and there was another shop—an old one—in the main works. In the new shop they could turn out work more cheaply than in the old one. In this latter case, the arrangement of the work and the mentality of the platers were such that they could only speak of riveting and it would take a long time to make a change and get them to think in terms of welded work.

There was a great deal of time wasted on outside welding which could be avoided. Boiler maker welders worked well when on the ground, but when the structure gained height they often objected to working aloft. In some instances they had been known to object to welders of other trades being employed.

Another cause of delay was that welders generally objected to doing any other work than welding. There were many reasons for delay during erection (viz. the lifting of bars, etc., and assembling ready for welding). If the welders would assist in such work, considerable saving would result.

As regards the responsibility of the rolling mills, he had had plates which had had to be scrapped because of laminations. He would like to go away from this meeting with the knowledge that some definite proposals were to be made whereby welded work got fair play. At present it seemed that a price for a welded job would be some 10 per cent. more than for a similar riveted job, but there was no reason why it should be. He would like to see the Institute take up the interests of welding people, compare notes with other bodies and get a common understanding so far as costs were concerned.

Mr. P. B. Crighton (London Welding Co. Ltd.) said that, after listening to Mr. Bondy, he had come to the conclusion that on-cost was the most vital factor in welding costs. Between 1939 and to-day the wage rates of welders, as far as he was aware, had risen by 40 per cent. on ship work and 63 per cent. on land construction and repairs. Further, in the case of a welding firm, the on-cost, calculated on what was known as the Admiralty Emergency Repairs Agreement, had risen in the same period from 30 per cent. to 75 per cent. Mr. Bondy had referred to on-costs as high as 250 per cent. where a firm was carrying out fabrications in steel of heavy tonnage with valuable equipment and automatic welding plant, producing pressure vessels, etc., that was quite understandable, but for general welding such as he was now referring to, 75 per cent. to-day was a relatively low figure. These rises in on-costs were not high compared with the increases in riveting costs in the same period in this country. When considering the fabrication of steel work for export, however, the increase in these costs was a very serious factor. Mentioning some of the factors to which he was referring, he said that transport had risen by 110 per cent., office charges, rents, insurance, rates had gone up, while fuel and power had risen by 55 per cent., standby holidays with pay and other non-productive labour had risen by 380 per cent., and workmen's insurance had risen by 195 per cent. These were factors which were largely beyond the control of the management. It was agreed that welding could be developed very considerably in this country provided there was the basic start of proper design and good welding procedure, but it was necessary to look outside the industry for control of the remaining establishment charges.

A Standard of Measurement

Mr. R. G. Braithwaite said there was one thing he was a little disappointed about on this question of costs, and that was that nobody had yet said exactly what was being costed. Nothing, or very little, had emerged as to how to measure the thing it was desired to cost. Before it was possible to talk about costs, it was necessary to have some standard of measurement. Coming up the stairs to the meeting that morning he noticed that the Institution of Civil Engineers was holding an examination for Section C. It was thirty-five years ago that he had come up those same stairs for that examination, which had included the measurement of civil engineering works. In other words those sitting for that examination had to know something about the measurement of the work on which they were engaged. One of the items in civil engineering was brickwork. That was quite a common sort of material and all of them in various trades and industries came up against brickwork in buildings, floors, etc. Those connected with the building trade knew that in every case the measurement of brickwork was reduced to one common factor, viz., a 9-inch thick wall. This volumetric basis had always been the standard he had endeavoured to use for welding measurements. In other words, the volume of weld metal deposited. In America they talked about pounds of weld metal deposited, but in this country the measure was so many inches or so many lineal feet. All this could be co-related down to some common standard. There had been papers written by himself and other authors on this question of measurement of welding, but it seemed to him there was one thing the Institute might do, and that was to arrange some form of conference or meeting, whereby they could all get together and see if they could decide how to measure welds. That was the first essential thing that should be done. It had always been one of his important problems. A designer came to him and asked if he designed, for instance, a bridge in a certain way, how could he judge whether it would be economic with welding; by what yardstick could he measure the work up? That was very difficult. Those who had done riveted structures knew that a certain job would require 300 or 400 rivets per ton and the cost could be worked out in terms of man-hours or in some other way. There was something to fasten on to, but in welding there was no corresponding unit that was universally recognised. If it could be said that the job had X-units of welding in it, the cost could be worked out more or less straight away. He hated to suggest that there should be another British Standard specification. There were a thousand of them already, but he felt there would have to be another one, and it would be the Institute of Welding that would have to initiate it.

Two points made by previous speakers interested him, viz., the proper use of electrodes, referred to by Mr. Silverwood, and the question of good housekeeping mentioned by Mr. Flintham. This had been an everlasting problem in the organisation of various works. They used 10, 20 or 30 tons of electrode material in a year and there was an enormous wastage. All sorts of methods had been tried to teach the welders to use electrodes economically but the point was that it was necessary to employ somebody to count the electrodes. That was easy enough before the war. A small office boy could get the welders to check in stub ends and then sort them out, but in these days of shortage of labour that was not possible. The biggest factor in economy in the use of electrodes had been introduced by the manufacturers of electrodes themselves, although inadvertently, because with the recent shortage of electrodes the men found that they could not earn their bonus—they were all on piece work—unless they had electrodes, and that led to great economy in their use. This was all tied up with the question of good housekeeping and perhaps the remedy was to starve the welders of electrodes.

Something had been said by Mr. Heigh about the Institute initiating classes in welding. Of course, under wartime conditions that was very satisfactory because there was no competition for leisure time. In the Midlands he himself, in a small way, had been trying to help the various technical schools to establish classes in welding, and a certain amount along similar lines was being done in his own firm. But under peace-time conditions it was not possible to get classes in welding working outside factory hours. It all had to be done in factory hours, because there were so many competing interests for leisure time. Moreover, people were studying for this, that and the other, and it was difficult for those concerned with the development of the welding industry to compete with these other interests. Therefore, it did not matter what energy was put into initiating classes, there would always be a limited response.

Mr. P. S. A. Berridge (Bridge Assistant, British Railways, Western Region, Paddington) said he thought a great deal of emphasis had been laid on economy in terms of lbs. avoirdupois without enough attention to £'s sterling. The British railways were very far behind in the maintenance of bridges to-day and there was a great deal to do in that connection. It would be agreed that a really economic design could be prepared with welding, and it should be possible to get the work done more cheaply than with riveting; but, recently he had invited tenders from eight firms for a simple job, and he found that the first seven tenders were identical to the nearest penny. When he inquired of the individual firms why that was so, they told him they were governed by a federation which in some cases prevented them from giving what they knew to be a fair price. Obviously, this was not competi-

tive tendering, and until this system was altered he did not see how fair comparisons could be made between the costs of welded and riveted work in this country.

The Chairman then called on Mr. Bondy to sum up the discussion.

The Opener Replies

Mr. O. Bondy felt he could agree with many of the speakers, but it was difficult for him to pick out individual items. However, he had been very much impressed by what had been said with regard to good housekeeping in shops and also the remarks with regard to waste. A great deal of waste had been going on for very many years not only in the welding field, but in many other fields, and something would have to be done about it by his hearers, not only as members of the Institute, but as those directly affected by the present economic emergency. Whether it was waste of electrodes or waste in design, it was the same thing in the end, and it was their duty to cut down waste wherever it was to be found.

He fully agreed with what had been said as to the hopeless task involved in trying to produce a good job based on a poor design, and he certainly sympathised with welding shops when they were asked to carry out a design which was poor or unsound from the beginning. That was a hopeless task and it was entirely unfair to judge the results or the possibilities of welded construction in any field by the results arising from inadequate design. It had been emphasised in many previous discussions that sound design should be the basis of all activity in welding, whether shipbuilding, structural engineering, boiler work or anything else.

Again, he could understand those who had expressed disappointment that this discussion had not brought out any concrete results, but after all, it was not the purpose of a discussion meeting to arrive at definite figures or results but rather to exchange views. Looking at the discussion in this way, he felt it was rather gratifying that the interest had been so lively and that so many aspects had been touched upon. They would all go home with plenty to think about and that, in the long run, would be the main beneficial result of this meeting.

The Chairman said there was present at the meeting a distinguished shipbuilder from Vancouver. It was delightful to have overseas visitors with them, and he would ask Mr. McLaren to propose a vote of thanks to Mr. Bondy.

Mr. McLaren (Vancouver) said he still had a Scots accent which he had acquired here. He had lived for about twenty years in British Columbia and had travelled extensively in the United States. He happened to be a member of the Institution of Civil Engineers, the Institution of Structural Engineers and the Institution of Naval Architects, and in this way he was able to keep in touch with what went on here. Moreover, he was pleased to say he had recently been elected a member of the Institute of Welding.

Ship Welding in Vancouver

He would like to say something of his experiences on the other side, although there was not a great deal of time. They were all interested in the dollar exchange and people over here were perhaps wondering why they could not sell more goods across the Atlantic. Up to the present, British goods had not been cheap enough, but perhaps with devaluation there would be a better trade with America and Canada. He did not know why Britain had not been able to sell more goods in those countries, because the wages here were much less than over there. In this country he understood that the average wage for a skilled workman was 3s. 8d. per hour, but over there it was 9s. an hour. They were working a 40-hour week over there and the men did not work on Saturdays. Moreover, there was no chance of their going back to anything else, and it need not be feared on this side that the workmen would be competing from the other side of the Atlantic by working longer hours.

In the matter of shipbuilding, they were intensive shipbuilders across the Atlantic during the war. They had all heard of Kaiser and knew of his work and his quality. He himself had been on a small Committee concerned with this work and it was very good on the whole. He was interested in shipbuilding in 1941, when the position was getting very serious, and he started shipbuilding, with the approval of the authorities, in the middle of that year. At the end of the year he was ready for operations and then turned out a ship every two weeks. The workmen consisted of miners, fishermen, logging men and odd job men. Schools of welding and riveting were set up and, as he had said, these people turned out a ship every two weeks. That was possible because the men were new to the job; they were not tired and they worked under great advantages compared with the men in this country because they did not have to contend with bombs. They worked for 168 hours a week in shifts throughout the 24 hours and 7,000 men were employed. Highly technical work was done by men quite unskilled when they first came to the job, but there was no difficulty in teaching them—and they were certainly very good students.

He was still doing a certain amount of this class of work, but he could not compete with this country, because the wage rate was 9s. an hour, and that was too big a differential as compared with the wage rate in this country.

Finally, he said it was a privilege for him to be asked to thank Mr. Bondy for opening the discussion and those who had taken part in it. He himself could say a good deal about the question of welding costs, but this was not the time, and it gave him very great pleasure to move the vote of thanks.

The vote of thanks was cordially given and the meeting closed.

DISCUSSION ON "THE WELDING OF BRIDGES AND ALLIED STRUCTURES"

By R. G. BRAITHWAITE, M.I.C.E., M.Inst.W., and

D. J. DAVIES, B.Sc., A.M.I.C.E., A.M.I.Struct.E.

The following is a selection from the illustrations shown when this paper was presented at the Autumn meeting of the Institute, together with a report of the discussion.

MR. BRAITHWAITE, introducing the paper, said he had to apologise, in the first place, for the omission of that part dealing with allied structures. It was found that in a paper of this description there was accumulated such a mass of information that it was difficult to compress the matter in a form in which it could be delivered, assimilated and discussed in a brief evening session. The paper was divided into three parts. The first dealt with the general problem of economics; the second part, which owing to the numerous figures and diagrams it had not been possible to get printed and published in time for this meeting, dealt with specific bridges and details of their construction, about which Mr. Davies would speak in a few minutes; and the third part dealt with some problems of welding of high tensile steel. It had been hoped to deal with some other forms of construction, but the subject was so vast that it was found necessary to cut out a lot of information which they would have liked to have brought forward for discussion. The paper, advance copies of which had been issued, had been written with the idea of promoting discussion. As a matter of fact, one of his colleagues who had studied the paper had pointed out that the comments in the paper on the essential differences between the fabrication of a welded and a riveted job did not, by any means, give the whole story and that many of the facts were over-simplified. That, however, had been done deliberately. The authors felt that in the time available it was not possible to go into everything and this over-simplification gave the opportunity of providing pegs on which to hang the discussion.

As the paper had already been published, he did not propose to read it, but he would now ask Mr. Davies to show some slides of bridges and describe some of the essential details.

Mr. Davies said the slides he was going to show were more or less representative of work in various parts of the world. He had selected them with a view to bringing out certain features in welding which, in many ways, might be considered as novel methods of fabrication. Some of the welded work done in recent years by bridge builders abroad might at times seem a bit risky to us—as for example the design of plate girders in Canada with ratios of web thickness to web depth of 1/270 or less (properly stiffened, of course), whereas in actual fact their fabrication had been based on quite a lot of rigorous research and experience and there had never been any trouble in the welding of suitable steels by well-tried procedures. As a matter of fact a good deal of this work abroad was quite conservative and followed conventional European practice. He proposed to deal with the slides in a certain order, commencing with simple spans, followed by continuous spans, arch bridges and finally frame bridges.

(A selection from the slides shown is printed overleaf.)

Mr. P. S. A. Berridge (Bridge Assistant, British Railways, Western Region) said the paper was most opportune and welcome at the present moment, and alluding to the authors' analogy about gardening, he remarked that he felt rather like a man who did not know which kind of flowers to order. The point was that if one started to design a bridge to-day it would probably be eighteen months or two years before the order could be placed for the steel and by the time all the forms had been filled up and the Town and Country Planning Authorities been satisfied there might be an electrode famine or a shortage of riveters, and the original design might by then be far from being the most economical.

He felt that the authors' statement that special rolled sections were not really necessary for welded work was most welcome. At the present moment we wanted to see the cost of fabricated welding coming down to a favourable limit in comparison with riveting.

At the risk of labouring the point, he said they all knew very well that the welded design must be entirely divorced from the principles of riveted design, but that was not quite so widely practised among other engineers who were not familiar with welding. Only recently a design for a footbridge—not very elaborate—was prepared for riveted construction, but when the time came to build it, welders were available but there were no riveters. He showed a reluctance to agree to welding because the drawing office was very busy and could ill afford the time to prepare duplicate drawings. "Oh," said the people wanting the footbridge, "that does not matter, we can use the same drawings!" But that was all nonsense, and it was necessary to break away from that sort of thing quite apart from the expense involved and the horrible appearance of a bridge designed for riveting and then welded. He could appreciate the gardener's point of view in not knowing what the consumer would want and, therefore not being able to plan his garden accordingly. In due course, no doubt, orders for fabricated steel work would flow and it was to be hoped that the gardener would be able to plan his garden more satisfactorily.

In the course of his work he visited many bridge and structural engineering firms up and down the country and was convinced that in the majority of works the cost of welded fabrication was higher than it should be because of "riveting" overheads. It was the old story of the tramcar and the bus over again. Capital had been sunk in batteries of drills and riveting machines and so on and all sorts of arguments were put forward against welding. It was said to involve trouble with distortion. They all knew that, but it could be overcome. Riveting suffered from the same complaint though to a much smaller extent. A riveted chord for a truss girder—two channels and a flange plate—would finish up concave on the flange plate side unless steps were taken to avoid distortion. Welds were said to localise and concentrate stresses. That was true, but so did rivets. In a large gusset, the stress in the rivets would be greater near the ends.

There were, however, pointers towards a broader outlook and he would quote two instances. The first concerned an English firm making steel railway wagons in a mass production way. They were the ordinary four-wheeled open mineral wagons for use in this country. In 1938 this firm was turning out ten riveted wagons in a five-and-a-half-day week, using 200 men. To-day, the same firm was turning out twenty-five welded wagons of exactly the same type with 100 men working a five-day week. Moreover, a director of the firm had told him, in all seriousness, that they could not turn out riveted wagons at that price to-day, and he went so far as to say that the young apprentices to-day were much keener on becoming welders than riveters, and that there was even a chance of riveting becoming a dead trade.

The second case concerned the replacements of Scottish railway

bridges washed away in the floods last year between Edinburgh and Berwick. Quotations were invited for either riveted or welded girder work, a matter of some 400 tons of fabricated steelwork involving a good deal of repetition. The tenders for the welded work were cheaper. For main girders, the welded work cost £58 per ton against £62 per ton for riveted work.

Probably welding called for more attention to detail in designing than riveting. The authors had very rightly stated it was necessary to cut out frills in welded design, but he was sure they did not mean that welding was only applicable when it had to deal with lumpy heavy plate girder sort of stuff, and that it was not so adaptable for light trusses. In this connection he showed the following slides:

Slide 1. This was a welded roof at the Karachi City Railway Station on the North Western Railway, Pakistan. He claimed this was an attractive design because the columns on the platforms were 50 ft. apart and the welded purlins helped to keep down the cost. This roof cost 9 per cent. less than a riveted design would have done, and, apart from that, he doubted whether the 26-inch deep triangular trusses could have been built up with riveted construction. The purlins were welded and the cantilever brackets and columns were riveted.

Slide 2. This was a detail of one of the purlins. They were made in the Jhelum Bridge workshops and they worked out economically. A large number were required and when the jigs were once set up they were used many times. There was no difficulty in transporting them on the Indian Railways and they arrived safely at Karachi 800 miles away from where they were made, and he did not see why we should not do the same in this country.

Welding lent itself to what he called elegance in steel work.

Slide 3 showed a stairway supporting girder at Lahore station. No one would choose curved steel work for economy, but there were times when æsthetics did count even in ordinary steel work, and in this case it would be agreed that welding had rounded off the corners, and that this would not have looked so well in riveted construction.

Slide 4. It was bad and expensive practice to combine welding and riveting in the same member of a truss, but there was often an advantage to be gained by adopting one or other system for complete components. This slide showed how welding had been used for part of a riveted structure, a 150-ft. railway bridge span between Amritsar and Pathankot. The cost of the built-up welded mild steel units was 350 rupees per ton compared with 450 rupees per ton for steel castings, so that there was a very definite saving in favour of the mild steel welded units.

Slide 5. This, said Mr. Berridge, was rather turning to the future. It was a proposed design for railway under-bridge construction in this country and combined welded girder work with pre-cast reinforced concrete. This design, evolved to simplify and facilitate maintenance—by avoiding the need for painting the underside of the deck—would hardly have been practicable but for welding. There was no welding *in situ*, the floor units being bolted to the stiffeners of the main girders. The nuts were pre-welded to the end plates of the cross girders. Attention was called to the erection bolt-holes, which could be used for drifting, etc., and lining up the girders. The tops of the cross girders were protected by an over-all water-proofing, and the tiles were to protect the bituminous felt from injury from ballast or platelayers' tools. As would be seen, the cross girder unit could be dropped down in between the main girders without having to displace the main girders laterally during the operation. In this case, he felt that welding certainly lent itself very distinctly to that sort of design.

Continuing, Mr. Berridge said he had spoken as if he were very much in favour of welding. He was in favour of it provided the cost could be brought down, but nevertheless he wished to give a word of warning. He remembered when he first started welding some sixteen years ago, there were people who were very keen on making fatigue tests, and he believed it was the Quasi-Arc Co. who first carried out tests on butt-weld specimens subjected to rapidly alternating fibre stresses far exceeding the yield point. The results showed failure under a number of reversals equal to about one-tenth the number which the parent metal could stand. Of course, girder work was not subjected to anything like the number of reversals that parts of machines were, and he would like to know more about that from somebody who was learned in metallurgy. He imagined that structural engineers excused themselves by saying that it was not the fatigue limit they need worry about but the yield limit, and apparently they did get high enough yield with welds. All the same, it must be remembered that the fatigue strength of the parent metal might be reduced as much as 60 per cent. adjacent to a weld.

Mr. J. E. Jones (Ministry of Transport) thanked the authors for their paper and for making their introduction to it short, because time did not allow of reading very long papers. Personally, he was much more grateful for a paper that suggested things and made one think than for one presented at great length in saying everything and leaving others nothing to think or speak about at all. The authors could not be accused of doing that.

There was one point he would like to raise in the form of a question. He was not quite clear what cost was referred to in the very first paragraph of the paper, where it was stated "There was no corresponding reduction in cost, and dissatisfaction was expressed with the high cost of welded work." Was the reference there to unit cost or the total cost? He was glad Mr. Berridge gave an instance of recent prices of welded work as compared with riveted work. He himself had heard of the case Mr. Berridge mentioned, and it was very gratifying to see that when a contractor put his mind to it, it was possible to get unit prices for welded work which showed a distinct advantage over riveted work. When coupled with that, there was also an overall saving in weight, the financial economy resulting from the adoption of welding was likely to be really worth having. He knew there had been a considerable amount of difference of opinion about the cost of welded work and therefore he would like to know to just what that reference in the first paragraph of the paper referred.

Talking of costs rather suggested that the whole cost of a job was not just the initial cost. Quite a lot was involved in the maintenance of it afterwards. When one looked at drawings and photographs of welded bridges or steel work, one could not help noticing how very clean and simple the whole thing looked. The slides had shown that up very clearly; with welding there were far fewer members and faces in contact which could not be got at for painting, etc., and welding did get rid of rivets and bolts, which were a thorough nuisance from the maintenance point of view. Trouble so frequently started at riveted joints and in considering costs, even if welded work came out a little more expensive than riveted work initially, it was necessary to remember the less maintenance that was called for as time went on. It was surprising how much maintenance did cost. It was not just a matter of one painting, but of several paintings over the years.

He would like to end up by asking another question, of Mr. Davies in particular. It was not, strictly speaking, confined to welding work, but he would like to know what was considered to be the range of bridge work in which the use of high tensile steels, coupled with welded work, was likely to be profitable. His own feeling was that for the small bridge—and it must be remembered that in this country 80 per cent. of the bridges were 50 ft. span or less—there was not a great field of application for it, but he would like to hear what Mr. Davies had to say on that point.

Mr. Braithwaite said that Mr. Berridge's remarks were very comforting in that he had actually been able to get some welded work done more cheaply than riveting. Mr. Berridge's references to work in India were very interesting and they certainly gave the impression that even in what might generally be regarded as backward countries, there was a considerable amount of enlightenment as regards welding, and there was no doubt that Mr. Berridge had been able to make full use of this fabricating tool.

An important point mentioned by Mr. Berridge referred to fatigue tests on the heat-affected zone. A great deal of research work had been going on for many years on this question of the fatigue of welds, and that was the reason why he had brought out in the paper the question of Izod impact tests, on the single pass weld. That was exactly the point he was trying to get at. The trouble with the Izod impact test was that it had taken us a

very long time to standardise the Izod test piece which would give consistent results. Anyhow, a test had been found and it was used a great deal. It was one of the tests specified in the classification of the electrode which must have a minimum resistance of 30 ft.-lbs. That was all very well, but very great care was taken in that classification to ensure that the weld metal on which these tests were being conducted was pure weld metal, that in making the test they did not get anywhere near the heat-affected zone and that the effect of impurities picked up from the parent metal were absent. In bridge work most welding was in the form of single pass fillet welds and therefore these tests were not the slightest use. By no possible means could a standard 10-mm. Izod test piece be cut out. Was it therefore possible to design a method or a test piece in which the impact value could be measured across the pure weld metal and across the heat-affected zone and across the parent metal. If that could be done we should kill one of the bogeys as to the possibility of fatigue failure in some part of the weld, heat-affected zone, or zone adjacent to it.

With regard to Mr. Jones' question on the first paragraph of the paper concerning costs, the authors definitely meant "all-in" costs, not cost per ton. As to the comparative cost of an article—it might be a roof truss, a girder, a floor section, a column, or something of that sort—a large number of cases had occurred in which the welded counterpart was of the order of 10 or 15 per cent. lighter than the riveted counterpart, but there had not been a corresponding saving in cost. It was the "all-in" cost that was the burden of the remarks in the first paragraph of the paper. The costs of a welded job were affected by the way in which the weld metal was employed. It was very difficult to lay down what was the economic amount of weld metal when designing for welded work. As a thought for them to take away, he said that roughly speaking, 3 in. of $\frac{1}{4}$-in. fillet weld gave the same strength as a $\frac{3}{4}$-in. rivet, but it was not possible to say whether the cost would be greater or less for welded work than for riveted work. But assume they were of equal cost value and then compare the amount of weld with the number of rivets. The number of rivets might be in the order of 400 to 600 per ton, but the weld would be in the proportion of 1200 rivets per ton. Excess weld was put in because of the failure to understand the economical distribution. Therefore a larger amount than was really necessary was put in to be safe: that was the answer to the whole thing.

Mr. Davies, continuing the reply, said that before getting down to the question put by Mr. Jones with regard to the use of high tensile steel for bridge work, he would like to deal with two points mentioned by Mr. Berridge. First, with regard to cost. He had already mentioned that the trends in this country were very difficult to define because so little bridge work had recently been done in this country. For this reason he had taken the trouble to examine the position in countries abroad, where there had been much more welded bridge work recently carried out than in Britain. In the United States a sufficiently large number of welded bridges of given types, e.g., continuous girders and rigid frames, had been constructed and these provided an opportunity to ascertain the cost trends in welded bridgework. Pre-war, the cost in the United States of welded bridge work averaged about £36 4s. per ton in 1938, and it was just about what the cost was here. In 1949, the prices of welded bridge work of the same types as above had risen to about £81 2s. per ton in the U.S.A. taking the old sterling/dollar exchange value. This indicated that the prices in America for shaped girder work were not very different from those that were quoted in this country.

Referring to the interesting slide shown by Mr. Berridge of the welding details connecting the floor girders to the main girders of a railway plate girder bridge, the deck system appeared to be resting on the bottom flange and he wondered if it was wise to have any floor load coming down on to the edges of tension flanges of railway girders.

On the question of reduced maintenance for welded bridges mentioned by Mr. Jones, this was confirmed by the Railway Authorities' allowance of 50 per cent. reduction in maintenance for welded work.

Regarding the use of high tensile steel for bridge work, he had examined the economy achieved in steel for road bridges of multi-span continuous deck plate girder type, with individual spans of up to 125 ft. This investigation was prompted by an enquiry made on behalf of the Sub-Committee on Steel Economy appointed by the Government. It was found that the use of high tensile low alloy steel accounted for a saving of up to 19 per cent. in the amount of steel, compared with welded mild steel for three span continuous girder bridges totalling 270 ft. in length. The saving in weight was, of course, affected by the greater deflection under live load of the lighter high tensile steel design compared with the more robust mild steel job; the modulus of elasticity being alike for the two steels. For highway bridges it would seem therefore that the total of spans for a three span continuous deck plate girder bridge would have to approach 400 ft. If there were to be any financial advantage by the use of high tensile steel for isolated bridge jobs involving relatively small tonnages of special quality steel. With a more general concerted demand for high tensile weldable steel the problem of its ready availability in correct quality would be overcome and this would lead to its wider use for short span highway bridges. Where bridges were of the open web truss type the use of high tensile structural steel was affected by different conditions than applied to shallow plate girder construction.

Instances of single span plate girder bridges built in high tensile steel for spans of about 100 ft. had been noted. It was assumed that the conditions governing their design were different from those applying to the usual deck plate girder highway bridge of shallow construction depth.

Mr. Berridge answered Mr. Davies' last point by drawing a sketch on the blackboard and explaining the construction referred to. On the question of the use of high tensile steel, he said that in the case of riveted structures he had found that between 75 ft. and 80 ft. was where the change-over took place for an ordinary three girder under-bridge in this country. Up to 75 ft., mild steel won, and then it was worth while thinking of high tensile steel, if it could be obtained.

Mr. J. M. Liddell (L.C.C. Chief Engineer's Department) said that welding suffered a severe relapse immediately after the war. During the war when thousands of special structures, Bailey bridges, components, etc., had to be constructed, thousands of additional welders were employed and these structures were turned out at considerable expense and under a great urgency. But after the war a recession came about and the question of cost came into the picture very largely, and he felt that the majority of engineers were not satisfied that welded construction represented a solution of structural work entirely, or even for the larger part. Welded details were very convenient for a great many cases, particularly those referred to by the authors, i.e., frame construction, plate girder work and machinery bedplates and bearings, and a wide range of articles for which normally castings would have been used. But lattice girder work was heavy and large joints had to be made in individual members, often on the site; he could not yet imagine site construction of such joints.

Another factor was that the majority of engineers and draughtsmen were not yet trained in welding technique. He imagined it would be many years before technical colleges and engineering schools would be turning out enough draughtsmen and engineers conversant with the different techniques required for welding work or to make sufficiently advanced drawings. He had had occasion to visit one or two structural engineering works since the war and had not noticed a tremendous enthusiasm for welded construction. In discussing the matter with one or two firms he gained the impression that they thought the position would settle down so that about one-third of structural work would be welded and the remaining two-thirds would be riveted. One reason for that during the last few years was the large amount of power station construction or expansion that was in hand. In a number of cases this work had been ordered on pre-war drawings and they were mostly riveted work. He did not think it would be generally agreed that riveted work would disappear. It had a great application and would be essential for a long time to come. On the other hand, he believed that welding would increase but its progress would be slow.

Mr. O. Bondy, after joining in the general thanks to the authors for a most interesting paper and a really impressive array of lantern slides, said that even more impressive was the whole history of welded bridge building in this country. It was in 1933 when the Middlesbrough bridge was built, and since then we had more or less relied on examples from abroad. For that reason it had been a great pleasure to see in the authors' lantern slides quite a few very good examples in Great Britain. One thing, however, was missing. It might be entirely his own fault if he had not noticed it in the paper, which he had not yet had an opportunity of going through carefully. They had heard from Mr. Braithwaite in previous papers an optimistic view with regard to the future of welded structures and especially bridge work, and it would be a relief to know that Mr. Braithwaite was still as optimistic as he had been on previous occasions. There were, naturally, disputes as to the cost of welded structures. Again and again the question of cost had arisen, and he did not propose to enter into an argument with regard to it on this occasion, as it was to be the subject of the discussion on the following morning. It might be that in some cases certain details that Mr. Braithwaite had pointed out explained the additional cost, but personally he rather felt that optimism should depend not on the question of an increase or reduction in the total cost, but rather be based on the fact that a well-designed welded structure ought to be, and must be, superior in many respects to a riveted design in order to compete against it. This point should be stressed again and again. If the welded structure was not better than the riveted design then something was wrong with the welding design or the welding procedure, or both.

Mentioning a technical point in the illustrations shown by the authors and in the sketch put on the blackboard by Mr. Berridge, he said he thought an application of this idea to welded bridges was worth mentioning, and that was to use a concrete bridge deck to strengthen the top and not the bottom flange. In the case shown on the blackboard he thought the strengthening effect of the bridge floor was rather wasted. It was good economy to prevent the buckling of the top flange by introducing a concrete floor as part of the main girders and incorporating it in the design. He believed this had been done somewhere on the Continent, but he was not sure whether the authors had already mentioned it in the paper. Some recent welded bridges in Spain showed some of these features. There had been a great deal of progress in this country during the past sixteen years, but a good deal more would be required before we could say that welded bridges had come to stay.

Mr. Braithwaite said he thought Mr. Bondy's reference to his optimism as regards the use of welded structures was hardly appropriate. Optimism was an emotion and he was sorry if, in the course of any lectures he had given, he had expressed emotion. He had always endeavoured to present facts, because engineers were more concerned with facts. The question as to the future of welded bridges or welded structures generally he thought had been answered by previous speakers. Mr. Liddell said he had been round various structural engineering firms and had found that the majority of the steel fabricators did not think that welding represented the final answer in the fabrication of steel work, but Mr. Liddell went on to say that they anticipated the thing would eventually settle down to one-third welding against two-thirds riveting. Personally, he would not argue with regard to the proportions between welded and riveted work, but he believed that in the course of the next ten or twenty years we should see a bigger change round than that. The answer at present was, as Mr. Liddell had put it, that a great deal of work was concerned with power station construction and extension and it was very natural in post-war reconstruction, whether building new work or adding to existing structures, to make use of the drawings and design the details on the basis of existing buildings and to make use of the same type of construction. As had been pointed out in the paper, it was difficult to marry welded and riveted construction in the same structure, and it was therefore necessary to go on gradually and get the new organisation together. The answer with regardto welding in bridge work was also wrapped up in Mr. Jones' remarks when he spoke of the cost of maintenance of the welded job being so much less than that of the riveted job. That, of course, was another aspect of the problem which would be very important in the future. It was unfortunate that too often people concerned with buying an article thought only of the first cost and did not take the maintenance of the article into account as much as they should, but it was a very important point. The result was that very often the cheapest and the simplest sort of job was put up. That, however, should not be the policy of British engineers, and as a matter of long-term policy this question of maintenance and æsthetic suitability should mean something more than cash value.

The question of the use of concrete, mentioned by Mr. Bondy, he would leave to Mr. Davies.

Mr. Davies said he was glad Mr. Bondy had raised the question of the use of deck concrete as part of the girder flange section. He believed it was a type of design of which engineers abroad had made full use in reducing the cost of their bridgework by anything from 10 to 20 per cent. over that for the all-welded non-composite construction. In the U.S.A. the trend now seemed to favour the use of composite welded girder construction to eliminate costly centering for concrete main girders as more economical in cost than reinforced concrete bridgework; but it was not yet certain whether this trend was general enough to merit closer attention. Some difference of opinion as to the advantage of composite construction had been expressed here at times and it was useful therefore to refer to its employment abroad for a large number of years and also to the D.S.I.R. (Building Research Station) programme of tests on this method of construction. Consultants in this country had in fact employed composite steel and concrete designs since 1938.

An important characteristic of composite construction was that of stiffness, which was substantially greater than in the non-composite alternative. For example, a given bridge girder designed without taking the concrete deck as part of the compression flange was allowed to deflect 1/600 to 1/650 of the span under live load. By attaching the concrete deck to the compression flange and even reducing the steel in the compression flange to a fraction of its original area the deflection of the girder was reduced to something like 1/1200 to 1/1300 of the span.

This principle applied, of course, only to bridges where the bridge deck was supported directly upon the compression flange of the steel girder. In certain designs, as for example continuous girders, the concrete was only fully effective as part of the girder section for a portion of the girder length.

In the slide and sketch shown by Mr. Berridge for a typical railway through plate girder bridge the deck was in the plane of the girder tension flange, so that the concrete deck did not lend itself to composite design, as would the deck on top of the main girders.

Mr. W. G. Carter proposed a vote of thanks to the Authors. He said he had been fortunate enough to be associated with a large welded scheme in this country which, when it was being formulated, raised many problems on the welding side. Rather than attempt to solve them all by pooling the knowledge within the office, he and his colleagues considered it best to go out and find what had been done elsewhere. General outside opinion inferred that answers could only be obtained by reference to such countries as Germany, Switzerland, Sweden, etc. (Incidentally, he said he was very surprised at Mr. Braithwaite's remark regarding India being a backward country, especially having in mind that Messrs. Braithwaites Ltd. had possibly done 50 per cent. of the structural work carried out there.) Information from abroad was, in the main, inconclusive, so endeavour was then made to find out what information was available in this country, and they were agreeably surprised to find that there was just as much knowledge of welding, and probably a little more, in this country as in the majority of other countries of which so much had been heard. In the scheme they had in hand, tests had been carried out on the welded work and results had proved very satisfactory indeed. Admittedly at present there was a shortage of experienced designers, but, provided proper control by suitable experienced senior men was established, he was positive that in this country we could turn out welded work as good as elsewhere and in suitable volume. He was not nearly as pessimistic about it as some people were or appeared to be from the discussion.

The vote of thanks was cordially given and was briefly acknowledged by Mr. Braithwaite.

LADBROKE GROVE (Fig. 1)

(Designed by L.P.T.B. for 18 B.S. Railway. Unit Loading + 50 per cent. impact. Put in service October 1938. First welded railway bridge in Britain.)

Type.—Double track through P.G. bridge of three main girders.

Span.—60 ft. clear, 66 ft. 9 in. overall.

Width.—Girders at 13 ft. 7½ in. centres.

Deck.—10 in., one 70-lb. joist in concrete at 20 crs.; 2 in. clear of girder tension flange.

Centre Girder.—Weight, 22½ tons (total for bridge 84 tons).

Web.—5 ft. 2 in. constant depth, ⅜ in. at ends, ½ in. for centre, with double V butt between, fillet welded to flanges.

Flanges.—Inner plate 20 in. × 2½ in. full length. Outer plate 18 in. × 2 in. × 44 ft. long, fillet welded, with ends tapered at 20 deg. to a rounded point and fillet welded, using ½ in. fillets, increasing to 1 in. at the narrow end, in place of ½ in. constant fillets which developed fine cracks near the pointed ends. In recent welded railway bridge work in Switzerland (Rupperswil Bridge, 1945) the end fillets at rounded corner flange plate ends have been increased in size using unequal leg fillets sloping at 20 deg. to the flange surface and the fillets ground smooth with a portable spherical rotary miller. Tests by Prof. Otto Graf (1942) show that the fatigue resistance under pulsating stress of 2×10^6 cycles on 22 deg. sloped end fillets increased from 6T/sq. in. to 9·7T/sq. in. when the weld size was increased from ½ in. to ⅝ in. throat. The influence of the unequal legs was not considered as important as the increase in throat of the fillet.

Stiffeners.—These are of 9 in. × 1¼ in. plate extending from the top compression flange, where small triangular gussets at the stiffer edge are fillet welded longitudinally to the flange, while at the bottom the stiffeners stop off on top of the floor joists, to which they are fillet welded.

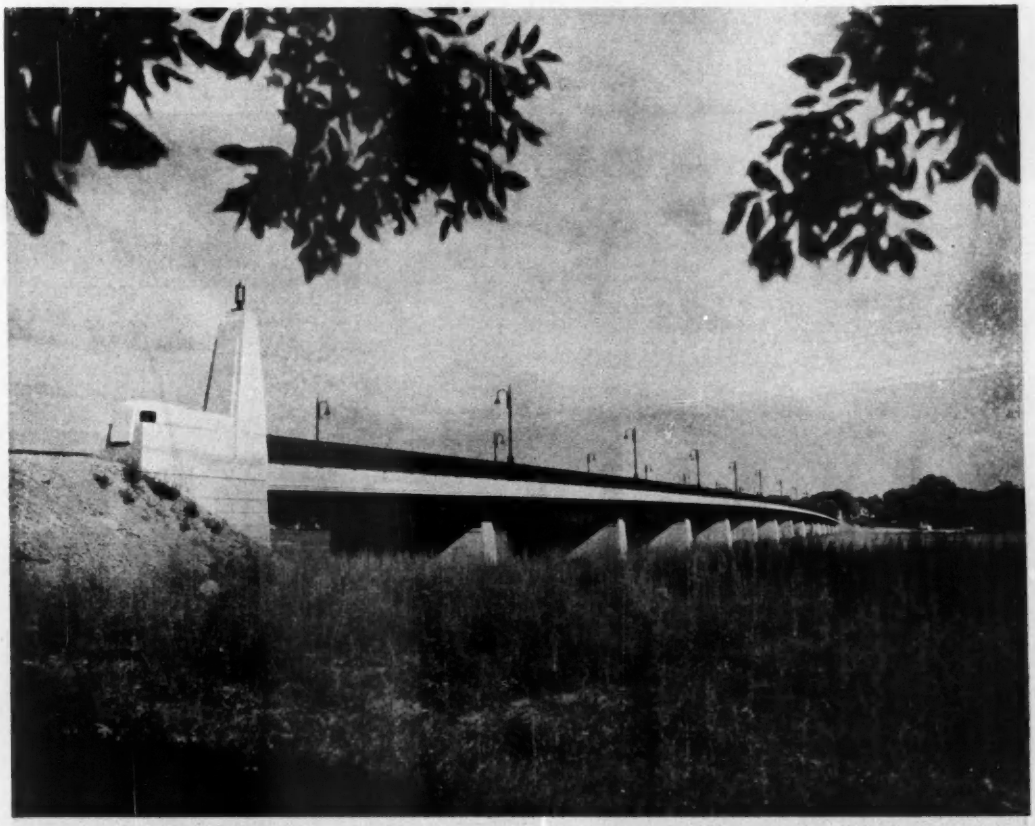
Shop Welding.—Girders fabricated in one piece. Flanges and web welded separately before assembly together; tack welding and completion of web to flange seams with the girders tilted at 45 deg.

Site Welding.—This applied between floor beams and girders the beams being delivered to site square ended to exact length.

Conclusion.—(1) Economy in material, 20 per cent.; (2) Economy in cost, 7 per cent.; (3) Quicker site erection and quieter.

BULWELL BRIDGE (Fig. 2)

This is typical of the form of construction employing pre-cast concrete jack arch centering, seated upon concrete haunched bases pre-cast to the bottom flanges of the main girder. Timber centering or shuttering is not required. Concrete for the bridge deck is placed on the pre-cast units to encase completely the girders, which are seen to be welded for this bridge. New designs prepared in accordance with B.S. 153, 1937, which stipulates that the compression flange shall be not less than the tension flange in gross area, but that a stress of 10T/sq. in. may be used in both flanges, when solid jack arch deck construction is employed. This design procedure, while extremely simple, exacts a considerable sacrifice in economy of steel as well as in cost, if we are to be guided by more up-to-date designs. The more satisfactory procedure is to design the girders for composite interaction with the concrete deck, thereby reducing the amount of steel in the compression flange, since the concrete functions as part of this flange if adequately bonded to the girder for this purpose by shear connectors, either as bent rods through the girder webs or as cleats welded to the compression flange to engage distribution rods in the concrete. Spiral reinforcement may similarly be employed. Economies in steel of up to 30 per cent. are practicable by this means, which applies equally well to other forms of on-site concrete decking.



ST. ROSE BRIDGE (Fig. 3)
(Over River Des Mille Isles, Quebec, 1945)

Width, Length.—Road bridge 52 ft. 8 in. wide, 1,548 ft. long, employing two main girders 32 ft. at crs. continuous for full bridge length. Over 14 spans from 90 ft. to 126 ft.

Load.—Live load 2/25T and 4/20 T trucks abreast or alternatively 100 lbs./sq. ft.

General.—Since 1936, Quebec Province have built fifteen similar bridges, apart from other shorter span jobs, six of them since the end of the war, involving 4,480 long tons of steelwork.

Temperature.—Range minus 40 deg. F. to 120 deg. F., giving 9·7 in. expansion at each abutment. Fixed bearings at centre pier, twin roller bearings 5⅜ in. to 6⅛ in. diameter at piers and abutments.

Girders.—*Depth*, 9 ft. max., 4 ft. 7 in. min.; *Flanges*, 22 in. × 1⅜ in. min., 2¾ in. max.; *Webs*, ⅜ in., i.e., h/t = 270 ($\frac{h}{t}$ up to 600 recorded); *Stiffeners*, 6 in. × 3½ in. × 5/16 in. L toe to one side only of web, designed as equivalent to two stiffeners. Bracket webs 5/16 in.

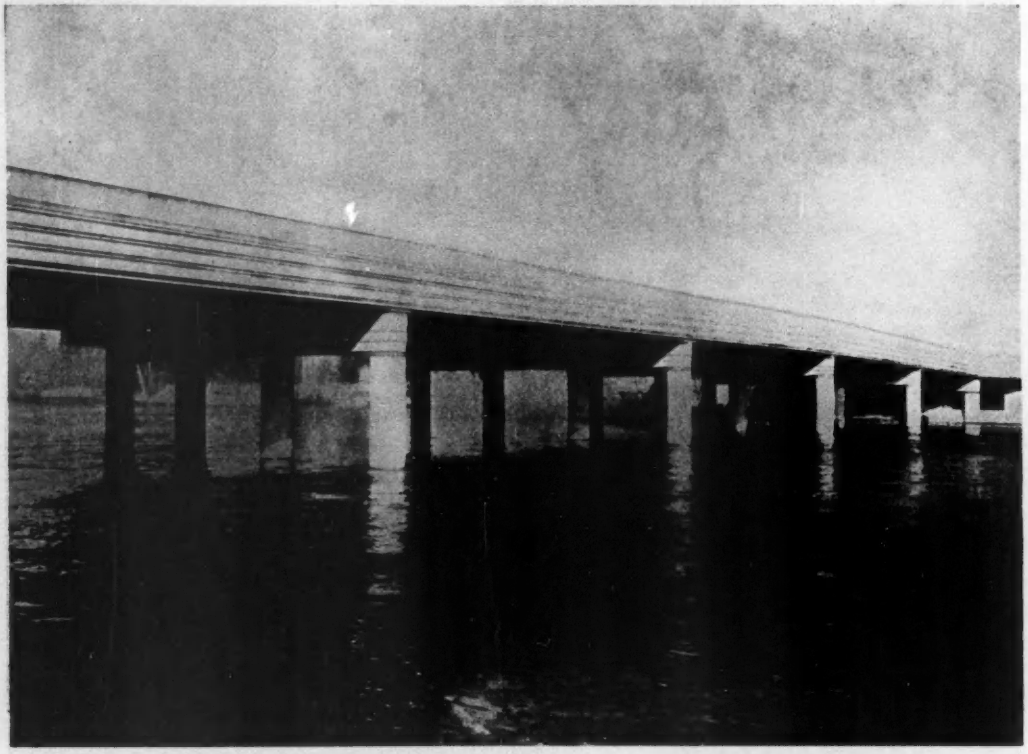
Bracing.—Temporary bracing used during erection and 8 in. R.C. deck acts as bracing for completed bridge.

Site Joints.—Site joints are at points of low B.M. using plate straps bolted to web and flanges to line up and control girder ends during butt welding. Holes out of flanges at these points of low B.M. not important. All bolts removed and holes plugged and welded. Procedure used at site altered to eliminate excess contraction in web when first joint was welded from centre of web outwards. For other joints the flange butts were welded for part of their depth, then the web welded for 12 in. from the flanges, flange welds completed next, then web weld.

Fabrication.—(1) Girder webs flame cut to shape allowing dead load camber. (2) Web details welded in place. (3) Flange plates butt welded in required lengths and pressed or rolled to correct curvature to suit the edge of the web. (4) Flange and web assembled and squared by temporary braces. (5) Fillet welds made in alternate runs on either flange in a sequence limiting distortions to ¼ in. (6) Girders flame cut to length and ends prepared for site butts.

Erection.—Girders erected by stiff leg derrick traveller. Site joints lined up with drift pins as erection proceeded, the error in girder elevation coming out at ¼ in. max. on an 8 ft. versine for the full bridge length. Site welding started after third span was erected and kept to this lag. Scaffolding for welders allowed full freedom for movement.

Concrete deck poured in lengths of 52 to 72 ft. First between D.L. inflexion points. Concrete supplied in 1½ cub. yds. side dump bucket cars on narrow gauge track. Twenty-seven road sections poured at rate of one per day.



ST. CLOUD BRIDGE (Figs. 4, 5)
(Over River Seine, Paris, 1940)

Type.—Continuous P.G. bridge of 7 spans carrying a R.C. deck for a road bridge 98·4 ft. wide.

Spans.—615 ft. total, made up of two end spans 49·2 ft. and five side spans 103·35 ft.

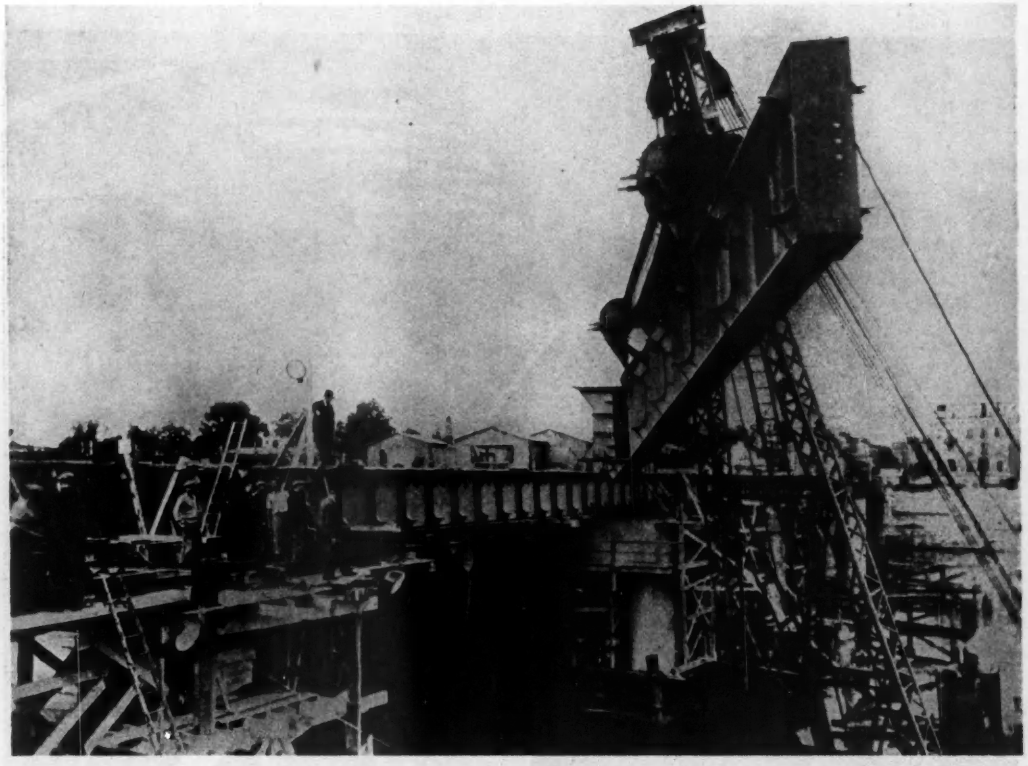
Number of Girders.—Thirteen lines of girders at 8 ft. crs.

Steel.—Ac 54 high tensile open hearth manganese steel 1·2 per cent. Mn, 0·22 per cent. C., 0·5 per cent. Cr, 0·5 per cent. Ni. Ult. 34/40·6T/sq. in. Yield point, 22·9/25·4T/sq. in. Elongation, 18/20 per cent. average. Careful inspection for lamination necessary.

Design.—This took into account maximum distribution of live load by means of the relatively closely spaced vierendeel transverse vertical bracing frames between main girders. Impact and fatigue were taken into account in permissible stresses used. The working stresses at points of biaxial stress where cross frame flanges are butt welded to girder flanges, were based on the principal stresses at such points.

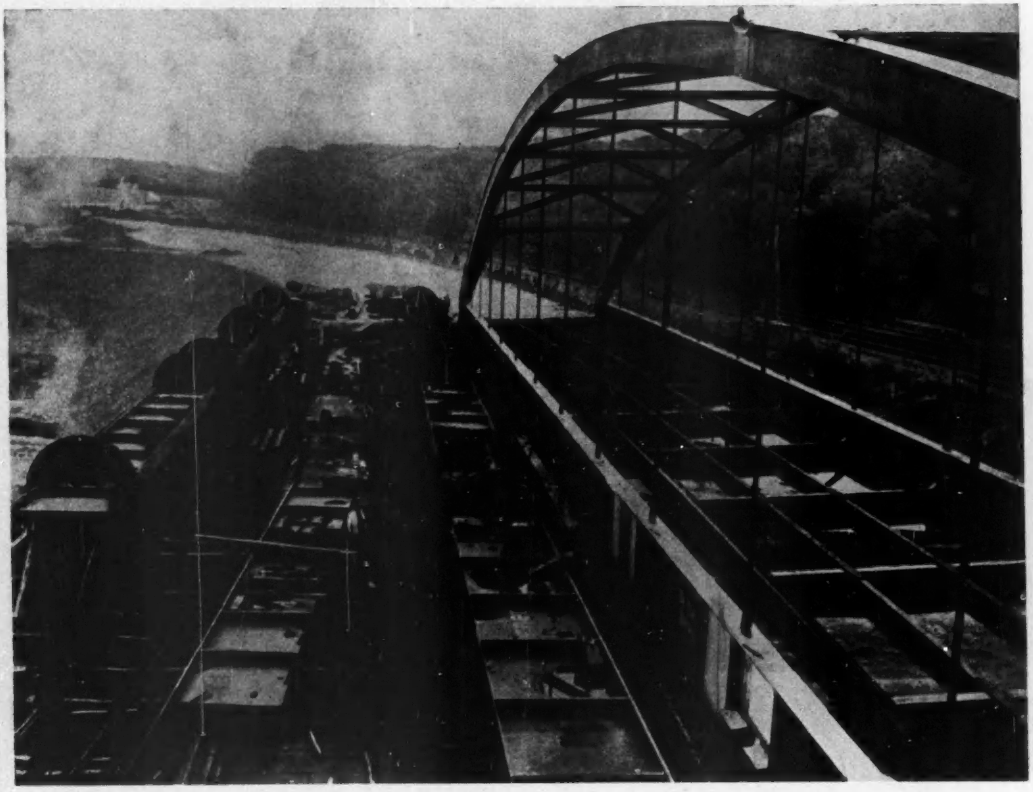
Girders.—*Flanges* of Wulst profile type (central triangular ridge) supplied from the rolling mills in ordered lengths. The mill tolerances resulted in many of these plates having to be machined to centre the ridge, apart from cases where planing was required to rid the material of lamination.

Welding.—(1) The girders were shop welded in lengths up to 103 ft. and 16 to 18 tons weight, site jointed between pier supports; (2) designed for maximum rigidity at intersections; (3) preference for butt welds over fillets; (4) minimum erection welds and their



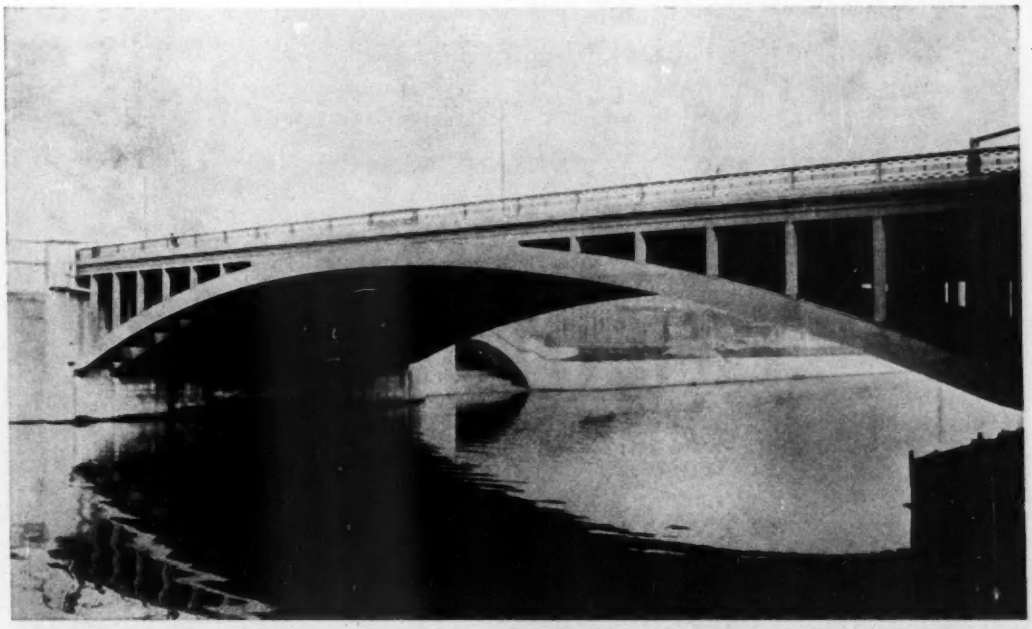
location at low stress points; (5) avoidance of sudden change in sections; (6) adherence to design and procedure requirements; (7) lock-up stresses kept to a minimum by weld sequence; (8) weld sizes and lengths based on lower permissible stresses than statical loading, by using reduction factors to cover for impact and fatigue.

Shop Welding.—(1) Flanges and webs separately welded in manipulator; (2) webs laid horizontally on blocks and flanges positioned by jigs and tack welded; (3) stiffeners and bracing frame-ends positioned on web in flat position and tack welded: the whole turned in manipulator and other side tacked; (4) web details welded to web before flange/web weld; (5) flange to web welds made by turning the work for each run; (6) web details welded to flanges; (7) all jigs allow free movement due to temperature effect; (8) lock-up stresses controlled by employing enough welders.



KAISERBERG BRIDGE, GERMANY (Fig. 6)

An interesting example of welded construction for a through arch bridge. It is axiomatic in welded bridgework that site welding be kept to a minimum, because of the lack of facilities as compared with shop work. However, when the structure is larger than usual the transport of built-up bridge pieces takes control, as these become too bulky and weighty if the site joints after erection are kept to a desirable minimum. To overcome this on larger bridges it often pays to set up a site works for welding smaller pieces into large units prior to erection. For this bridge of 338 ft. span this idea was adopted as best, and the assembly carried out in rotating jigs or manipulators so that downhand welding could be used. In all 1,200 tons of steel went into the job. This method of site fabrication has been adopted for the heavy crane girders of the Abbey Works, Margam, South Wales.



NEUILLY BRIDGE (Fig. 7)
(over River Seine, Paris, 1942)

Type.—Two deck-arch spans over two arms of the river. There are twelve lines of ribs supporting a road deck 115 ft. wide. Box type ribs and posts used.

Spans.—269 ft. and 220 ft.

Rise/Span.—1/12, 1/10.

Rib Depth/Span.—1/54, 1/57.

Steel.—Ac 54 high tensile open hearth manganese steel. Ultimate, 34/40·6T/sq. in. Yield point, 22·9/25·4T/sq. in. Elongation, 18/20 per cent.

Electrodes.—Weld Metal test. Ultimate, 34·4/39·5T/sq. in. Yield point, 28·6/31·8T/sq. in. Elongation, 19/26 per cent.

Acceptance Standard for Steel Based on: (1) Bend test of welded joints. (2) Hotch bar impact tests. (3) Control of scrap and other ingredients used for making the steel. (4) Control on "killing" of the steel, cropping of ingots, and rolling temperature.

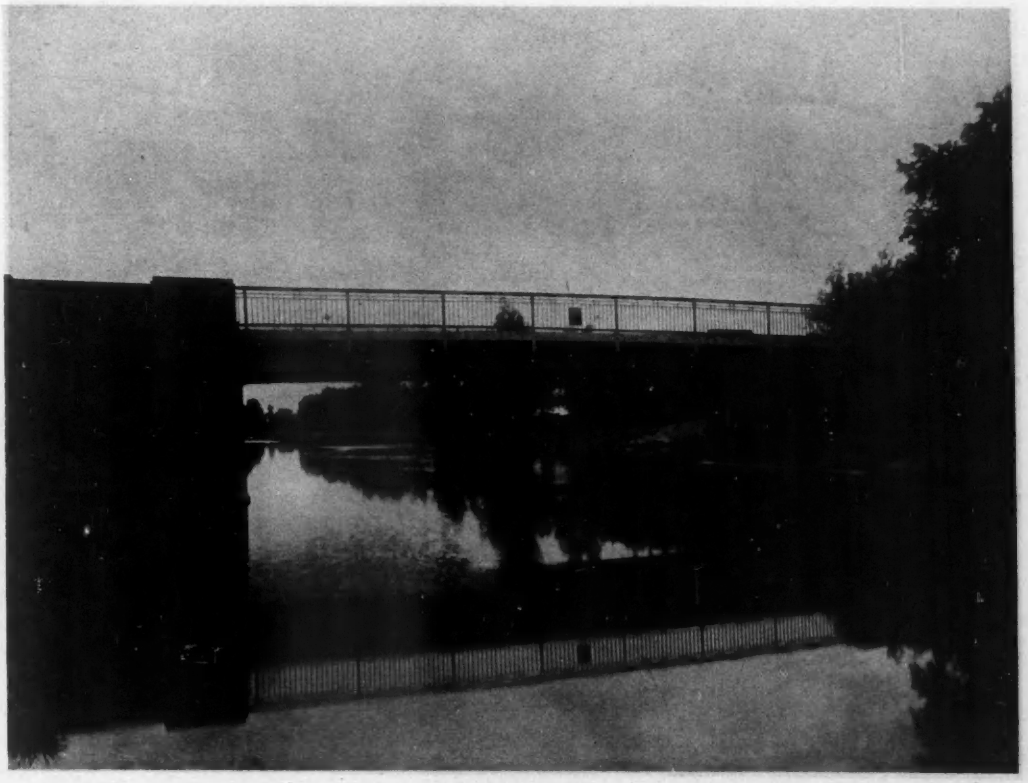
Rejections.—*Steel:* About 2 per cent. due to laminations and flaws; *Electrodes:* 2·2 per cent. *Notes:* The ratio of Mn to C (1·2 per cent. to 0·22 per cent.) is 5·45. British research recommendations suggest a minimum of 3. The notch toughness increases with this ratio up to about 5.

Fabrication of 269 ft. Span.—Box section ribs 60 in. deep, 24 in. wide, fabricated in 26 ft. lengths, then shop jointed into 52 ft. lengths. These joints are of the sleeve type, the end of one rib section fitting over the sleeve in the end of the abutting section. Ribs delivered to site in 52 ft. lengths (5 to one arch rib): the sleeve joints facilitated alignment with the aid of very few bolts, and the single V butt welds were all made from the outside, with the sleeve acting both as a backing plate and to prevent twist of rib.

Erection.—Temporary truss girders above the road level carried a travelling crane, which lifted the rib sections for attachment to suspenders from the trusses. The bridge was constructed in three sections of one-third the final width at a time, the central section being completed last.

BILLINGHAM BRANCH BRIDGE, DURHAM (Fig. 8)

This was the first all-welded bridge built in Britain and was opened to road traffic in February, 1934. It consists of five spans with a total length, centres of end bearings of 216 ft. and a full road and footway deck width of 58 ft. The roadway live load for the design was a 100-ton, four-axled vehicle plus 50 per cent. impact, together with a distributed live load of 150 lbs./sq. ft. Portal frame construction is used for the two 48 ft. intermediate spans, the beams of the portals cantilevering 8 ft. towards the abutment bearings over the 28 ft. end spans and cantilevering 12 ft. on the other side into the 64 ft. centre span to carry the 40 ft. long suspended girders. In the end spans the suspended girders are 20 ft. long. There are seven lines of frames under the road deck, and one each under the brick parapets. Being in the nature of a pioneer job a good deal of care was taken in the design and in the welding, and tests for the efficiency of connections were the order of the day. For this site where the soil is soft for a considerable depth the effect of approach embankment weight in causing heaving of the ground surface local to the railway tracks was important. In addition, the weight of superstructure had to be kept to a minimum, since bearing strata was 70 ft. down in places. These factors led to the use of welded portal construction for the superstructure and spill through "A" frame reinforced concrete abutments on piles constructed by the Rotoniff principle. The intermediate foundations are carried on 18 in. piles driven vertically and to stabilise the foundations against lateral movement there are strutted apart by a system of reinforced concrete beams just below ground level.



(Welded Frame)
Span 65 ft. crs of frame bearings.
Width 26 ft. between parapets.

CLAYHITHE BRIDGE, CAMBRIDGESHIRE C.C.
(Figs. 9, 10, 11)

An attractive example of a rigid frame bridge of 65 ft. span is shown. This is of welded construction, two main frames being sufficient to support the dead and live loads on a 26 ft. width of bridge deck. The choice of this type was influenced by the fact that this part of the river is much used for boating, so that the maximum clearance under the structure is important. Enhancement of the appearance as well as economy in floor system resulted from the cantilevering of the parapet sides of the deck outside the main frames, so that reversing bending movements are imparted by the cantilever brackets to the cross girder ends, where these connect to the main frames, which are 20 ft. 8 in. apart between webs.

As in all welded bridgework, the design was controlled by the

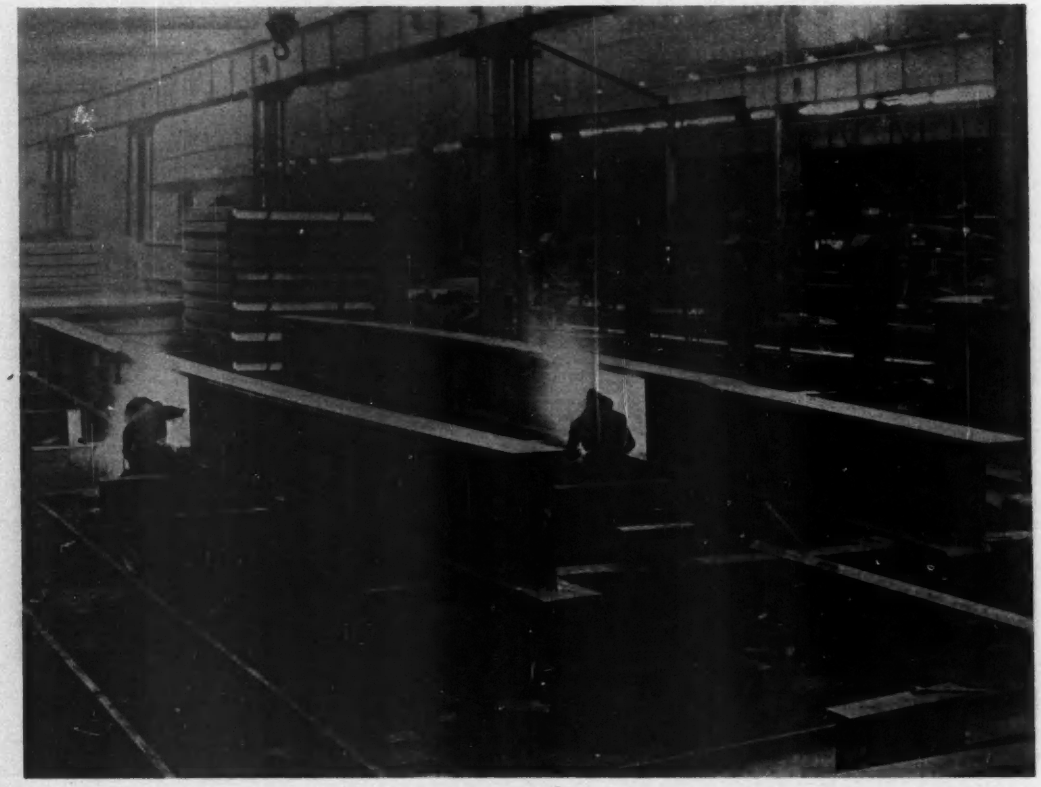


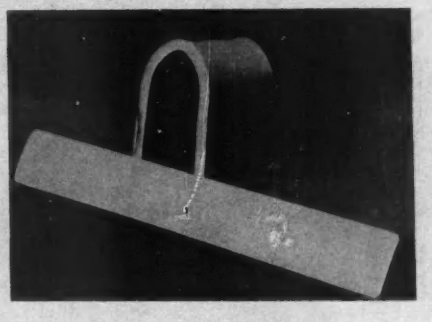
Fig. 10. Clayhithe Bridge

method of fabrication and erection. In this instance the main frames were each shop welded in three units complete with deck cantilevers and pipe deck soffit plates, there being two L-shaped leg units with end parts of the portal sway bracing frames welded-on and one beam unit per main frame. These were, therefore, delivered to the site, leaving the minimum of site welding to be done. A further important point concerned the design of the hinged bearings, to simplify the erection and pre-stressing of the structure, after site welding. These bearings are of 90 deg. L shape, the included angle carrying the journal for the bearing pin. This form simplified levelling and horizontal adjustment of the bearings. One pair of bearings was correctly located and grouted up on the abutment, while the opposite pair was levelled up without grouting to permit free contraction of the frames due to the welding of their site

Fig. 11. Clayhithe Bridge. Welded Portal Frame Leg.

butt joints. When the whole of the steelwork had been erected and the site joints welded, hydraulic jacks at the free end applied the correct horizontal thrust for the erected weight and the bearings were then secured and grouted.

For the erection, simple timber staging was temporarily placed in the river at 10 ft. from the bearings. The frame ends were then hoisted by crane onto their bearings, so that the free ends rested on the staging. Following this their connecting brace frames and cross girders were erected and located by temporary bolts and erection cleats. The centre units and their cross girders were next erected and temporarily bolted in the correct positions. Welding of all site joints was then put in hand, working to a predetermined procedure for balancing the effects of welding heat.



BEND TEST (Fig. 12)

This shows a typical sample bend test for determining:
(i) The quality of the parent steel after welding the joint.
(ii) The quality of the weld metal.
(iii) The relative ductility of weld metal and parent metal.
(iv) The relative yield points of weld metal and parent metal.

The specimen shown is a single V butt welded B.S.968 type high tensile welding quality low alloy steel; milled steel electrodes being used for the butt weld. This explains the tendency to ridging at the vertex of the curve portion, since the yield point of the parent metal is greater than that of the weld metal, which elongates more readily. If the weld deposit is suitably ductile the test will show no fine cracks in the weld surface. If cracks appear in the parent metal it is not of suitable welding quality. If the curvature at the bend is smooth the yield points of parent metal and weld metal are much alike.

WHIROKINO BRIDGE (over Manawatu River, New Zealand)
(Not illustrated)

Type.—Seven-span continuous deck P.G. bridge and R.C. deck 24 ft. wide by 590 ft. long.

Spans.—60 ft. to 110 ft. each.

Girders.—Four lines spaced at 6 ft. 8 in., 36 in. deep. Fabricated from split U.S. broad fig. beams and $\frac{1}{2}$ in. fillet web.

Erection.—By dragline with bucket removed working on dry river bed and on a barge in the river channel. Steelwork located on falsework for lining up and site welding.

General.—A number of other welded bridges have also been built on similar lines, e.g.,

Tangiteroria Bridge

Spans.—Seven spans of 59 ft. to 120 ft. each.

Maungatautari Bridge

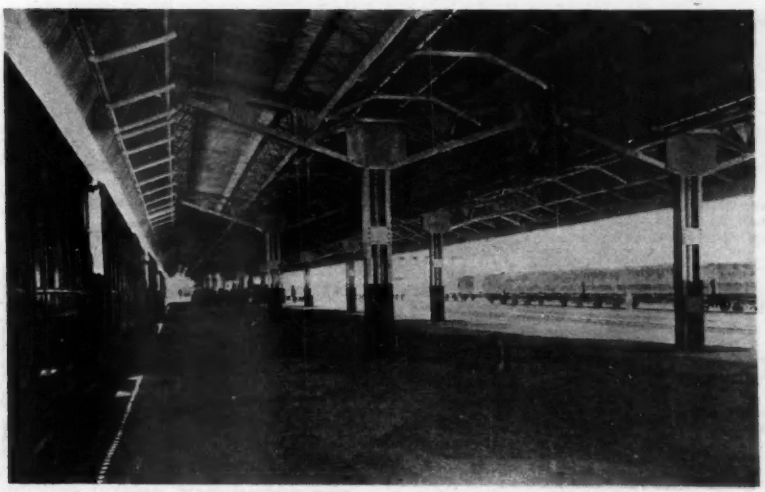
Spans.—Nine spans of 60 ft. to 130 ft. each.

Rangitikei Bridge

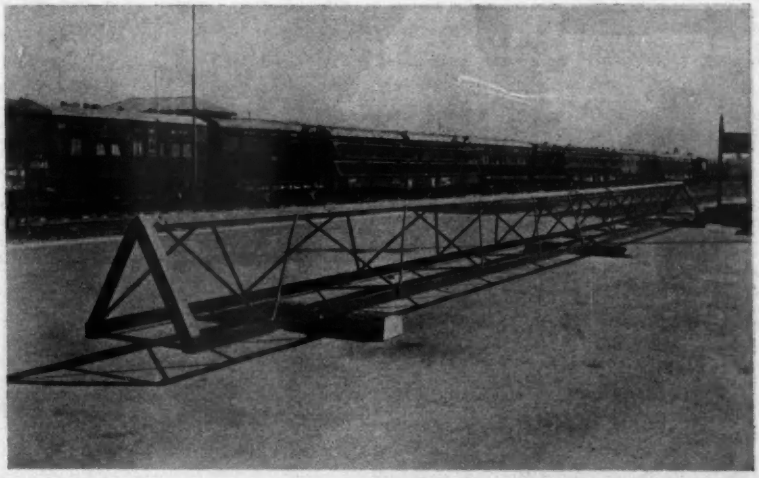
Spans.—Seventeen spans of 66 ft. to 88 ft.

Fabrication.—(1) Broad fig. R.S.J.'s oxy-acetylene flame cut by creeper cutter, using a special head which simultaneously cut and prepared the edges on both sides for a 60 deg. V butt weld. (2) Straightening of the cut sections was by spot shrinking on the flanges, and for deeper sections strong backs were used to assist the straightening. (3) Web longitudinal butt welds made by alternate runs on each side, the unit being turned each time. (4) Stiffeners were welded with intermittent welds to avoid distortion.

Erection.—Care was required in the sequence for pouring the concrete deck slab so that correct levels were achieved for the finished bridge deck.



Slide 1. Platform Shelter Karachi City Station, North Western Railway, Pakistan.



Slide 2. 50 ft. All-welded Purlin for Platform Shelter at Karachi City Station.

Slide 3. All-welded Plate Girder supporting stairways at Lahore Station, North-Western Railway, Pakistan.

Slide 4. All-welded Rocker Bearing for 150 ft. span of Railway Bridge, Punjab Railway, India

Latest Additions to the Library

As a supplement to the Library catalogue, this section of the *Transactions* contains particulars of books and pamphlets added to the Library during the first quarter of this year. The books, pamphlets and periodicals specified are available on loan to members of the Institute.

Publications preceded by an asterisk are donations to the Library from authors or publishers; those preceded by a dagger are donated by the James F. Lincoln Arc Welding Foundation.

ALUMINIUM DEVELOPMENT ASSOCIATION
Aluminium and aluminium alloy extruded sections (design and tolerances). 1949. (Information Bulletin No. 16.) Publishers: Aluminium Development Association, 33, Grosvenor Street, London, W.1. Price: 1/-.

BONDY, O.
The Bailey suspension bridge. (*Reprinted from* Engineering, *1949, June 24.*)

BRITISH ELECTRICAL AND ALLIED MANUFACTURERS' ASSOCIATION (INC.) *and* **INSTITUTE OF WELDING**
BEAMA-IOW British electrode classification covering manual arc welding electrodes for welding mild steels. 1949. (The list of electrodes with their manufacturers has been brought up to date.) Publishers: British Electrical and Allied Manufacturers' Association, 36 and 38, Kingsway, London, W.C.2. Price: 1/-.

BRITISH STANDARDS INSTITUTION
(No. 1500-1949.) Provisional British standard code fusion-welded pressure vessels for use in the chemical and allied industries. Publishers: British Standards Institution, 24/28, Victoria Street, London, S.W.1. Price: 25/-.

BUTLER, H. E. J.
Electric resistance welding: a practical guide to spot, seam, projection and butt welding methods. 1950. Publishers: George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Price: 17/6.

CHURCHILL, H. D., and AUSTIN, J. B.
Weld design. Illus. 1949. (This volume is devoted to welded machine-base design with data on materials of machine bases, stress-analysis, application of welded design principles, welding specifications, procedure, processes, flame cutting and flame hardening, forming of metals, and estimating welded machine-base costs. There is a comprehensive bibliography.) Publishers: Prentice-Hall Inc., 70, Fifth Avenue, New York, 11. Price: 6 dollars 65 cents.

CRAWFORD, E.
Questions and answers on electric arc welding. 1949. Publishers: George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Price: 5/-.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
Translated contents lists of Russian periodicals, no. 6, Nov. 1949, *to date.* (A number of organisations have co-operated in the work of translation.) Publishers: Department of Scientific and Industrial Research, Rex House, 4-12, Regent Street, London, S.W.1.

GRIESE, F. W.
Die Wirtschaftlichkeit der Schweissverfahren im Anwendungsgebiet der Rohrschweissung. 1949. Publishers: F. Vieweg & Son, Braunschweig. Price: 15/-.

INSTITUTE OF WELDING
Handbook for welded structural steelwork. 5th ed. 1949. Publishers: Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1. Price: 10/-.

KLÖPPEL, K.
Über Bruchfestigkeiten geschweisster Stahlbauten unter Berücksichtigung bekannter Schadensfälle. 1947. Publishers: F. Vieweg & Sohn, Braunschweig. Price: 2.50 DM.

NATIONAL PHYSICAL LABORATORY
Report for the year 1947. 1949. Publishers: H.M.S.O., York House, Kingsway, London, W.C.2. Price: 1/3.

NATIONAL RESEARCH COUNCIL
Handbook of scientific and technical societies and institutions of the United States and Canada. 5th ed. 1948. Publishers: National Research Council, National Academy of Sciences, Washington, D.C. Price: £2.

RIVISTA ITALIANA DELLA SALDATURA: ORGANO UFFICIALE DELL' ISTITUTO ITALIANO DELLA SALDATURA
Vol. 1, no. 1, Sept. 1949, *to date.* Publishers: Istituto della Saldatura, Via Valfonda, 9, Firenze. Price: L.600 a copy.

RÔS, M.
La fatigue des métaux. 1949. (L.F.E.M. No. 160.) La fatigue des soudures. 1948. (L.F.R.M. No. 161.) Publishers: Laboratoire Fédéral d'Essai des Matériaux, Zurich.

SEFÉRIAN, D.
Les soudures: technique, métallurgie, contrôle des soudures. Illus. (With bibl.) 1949. (The author, a professor at the École Superieure de Soudure Autogène, presents comprehensive data on every aspect of gas and arc welding. One of the most important sections is devoted to the metallurgy and weldability of metals. The mechanical properties of welds and testing methods are considered in detail. The final section deals with oxygen cutting, brazing, and the welding of plastics.) Publishers: Sfelt, 12, Rue Hautefeuille, Paris, 6. Price: 950 francs.

THOMPSON, R. N. and HAIM, G.
Welding dictionary: French, German, Spanish, English. 1950. Publishers: Louis Cassier Co. Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 25/-.

TIN RESEARCH INSTITUTE
Fusible alloys containing tin. 1949. Publishers: Tin Research Institute, Fraser Road, Greenford, Middlesex.

WEISS, E.
Tabellen für die Ermittlung der Widerstandsmomente und des Gewichts geschweisster Blechträger von 900 bis 3000 mm. Stegblechhöhe mit verschiedenen Stegblechdicken und Gurtplattenbreiten. 1949. Publishers: Wilhelm Ernst & Sohn, Berlin. Price: DM. 4.20.

TRADE CATALOGUES

ALLIS-CHALMERS MFG. CO.
Directory of products and literature. New Ampac "200" A.C. welder. Weld-O-Tron electronic arc welder. Weld thin metals with the Weld-O-Tron. Address: Milwaukee, Wisconsin, U.S.A. London Office: 728, Salisbury House, London Wall, London, E.C.2.

BIRMABRIGHT LTD.
(1) Applications. (2) Aluminium alloys for marine purposes. (3) Birmabright in marine construction. (4) Birmetals: applications. (5) Extrusions. (6) Light alloy extruded sections. Address: Birmabright Ltd., Woodgate Works, Quinton, Birmingham, 32.

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JAMES BOOTH & COMPANY LTD.
Brass and copper alloys. 1949. Address: Argyle Street Works, Nechells, Birmingham, 7.

BRITISH INSULATED CALLENDER'S CABLES LTD.
(1) Service to industry. (2) "Bicaloy" for resistance welding possessing high thermal and electrical conductivity developed especially for use with resistance welding machines. (3) Electric resistance welding. (4) Resistance butt-welding machines. (5) Resistance spot-welding machines. (6) Resistance seam-welding machines. 1949. Address: British Insulated Callender's Cables Ltd., Norfolk House, Norfolk Street, London, W.C.2.

EMPYRIUM WELDING AND MANUFACTURING CO. LTD.
Range of welded fabrications. 1949. Address: 50-55, Pritchett Street, Birmingham, 6.

SAMUEL FOX & CO. LTD.
Red fox electrical resistance alloys. 1949. (These comprise Red Fox 135, a chromium-iron-aluminium alloy for temperatures up to 1300° C., Red Fox 80/20, a nickel-chromium alloy for temperatures up to 1150° C., Red Fox 65/15, a nickel-chromium alloy for temperatures up to 900° C.) Address: Stocksbridge Works, nr. Sheffield.

HANCOCK & CO. (ENGINEERS) LTD.
Electronically controlled oxygen cutting machine. Illus. 1949. Address: Progress Way, Croydon, Surrey.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD.
The Metrovick type AS 300/27P welder. 1949. (A versatile spot welder for use in the manufacture of articles too bulky to be handled on pedestal type spot welders.) Address: Moseley Road Works, Trafford Park, Manchester, 17.

NEWTON VICTOR LTD.
The Raymax crystallographic X-Ray unit for X-ray crystallography. Address: 15, Cavendish Place, London, W.1.

ROCKWELD LTD.
Alumend: electrodes for manual arc welding aluminium and aluminium alloys: specification and technical data. 1949. Address: Commerce Way, Croydon, Surrey.

WILLEM SMIT & CO.'S TRANSFORMATORENFABRIEK N.V.
Electroden catalogus. 1949. Address: Willem Smit & Co.'s Transformatorenfabriek N.V., Groenestraat 336, Nijmegen, Holland.

THOS. W. WARD LTD.
(1) Handling gear: winches, blocks, hoists, jacks. (2) Vernier measuring instruments. 1949. Address: Albion Works, Sheffield.

A. S. YOUNG & CO. LTD.
Colmonoy hard facing alloys: (Wall Colmonoy Corporation, Detroit). Address: Tower Works, Woodside Lane, London, N.12.

OVERSEAS CORRESPONDENTS IN THE MIDLANDS

Welding, the Institute and the International Institute of Welding were the main themes in an interesting visit to the Midlands on 19 January, organised by the Ministry of Supply for a number of foreign press correspondents drawn from seventeen overseas countries. The party went to the works of W. G. Allen & Sons (Tipton) Ltd., and of Thompson Bros. (Bilston) Ltd. At the first they were welcomed by Mr. R. Weddell, joint Managing Director, who is also Chairman of the Birmingham Branch of the Institute and of the General Purposes Committee. At the second they were received by Mr. Howard Thompson, President of the Wolverhampton Branch of the Institute. At both works they had excellent opportunities of seeing the application of welding to British export products and the importance of the process as a means of increasing productivity and reducing costs was emphasised.

WELDING RESEARCH AND PRODUCTION

B.W.R.A. EXHIBITION

Sir Ben Lockspeiser, Secretary of the Department of Scientific and Industrial Research, made a strong plea for increased financial support for the British Welding Research Association, when opening the exhibition on Research and Production at the Association's London premises on 6 February last. Outlining the growth of the industrial research association movement, Sir Ben described as "measly" the current income of the Association, amounting to £57,000 a year, and appealed to industry to see that the figure was raised to £100,000 before the end of 1950.

The exhibition, which was visited by 1,256 persons during the week in London, was remarkable for the excellence of the display and for the variety of objects shown in the comparatively small space available. A series of talks and film displays had been arranged in connection with the exhibition, and the attendance at some of these was so great that arrangements had to be made at very short notice to accommodate them in larger halls in the neighbourhood of 29, Park Crescent. The sections of the exhibition illustrating the development of argonarc welding of stainless steels and the light alloys, the applications and control of resistance welding, and the use of non-destructive testing apparatus, including ultrasonic equipment, were specially notable. Other sections dealt with welded structures, repairs by welding, the welding of pressure vessels and pipe lines and of high tensile steels. Emphasis was given to the liaison work of the Association, and some visitors took the opportunity to bring their production problems with them for examination and discussion.

The exhibition was moved to the Engineering Centre at Glasgow for a further display lasting a week.

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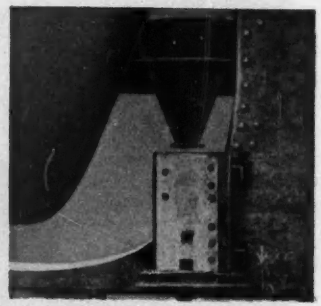

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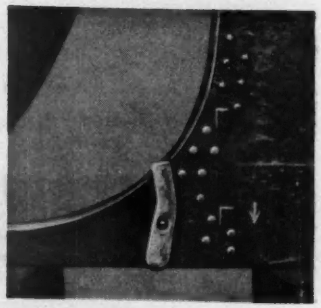

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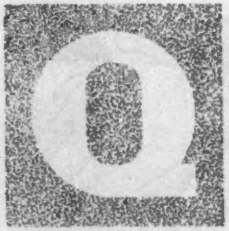

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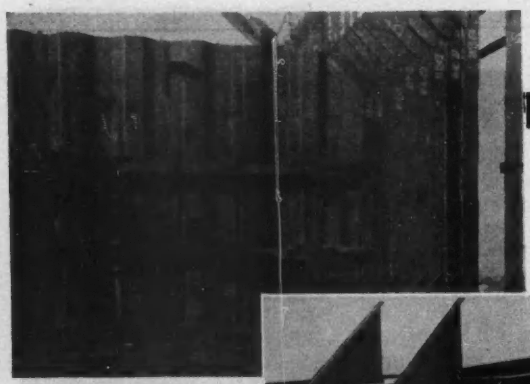

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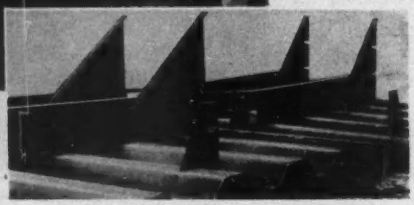

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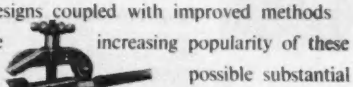

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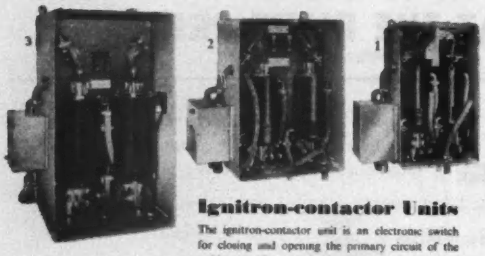

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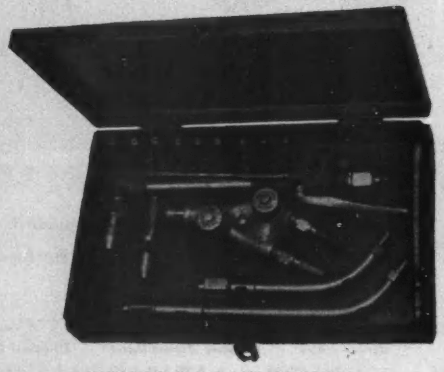

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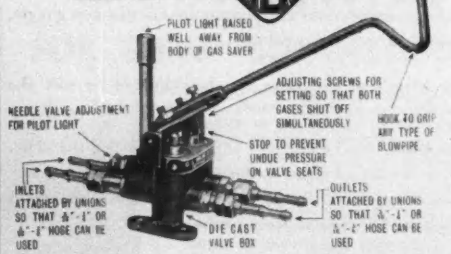
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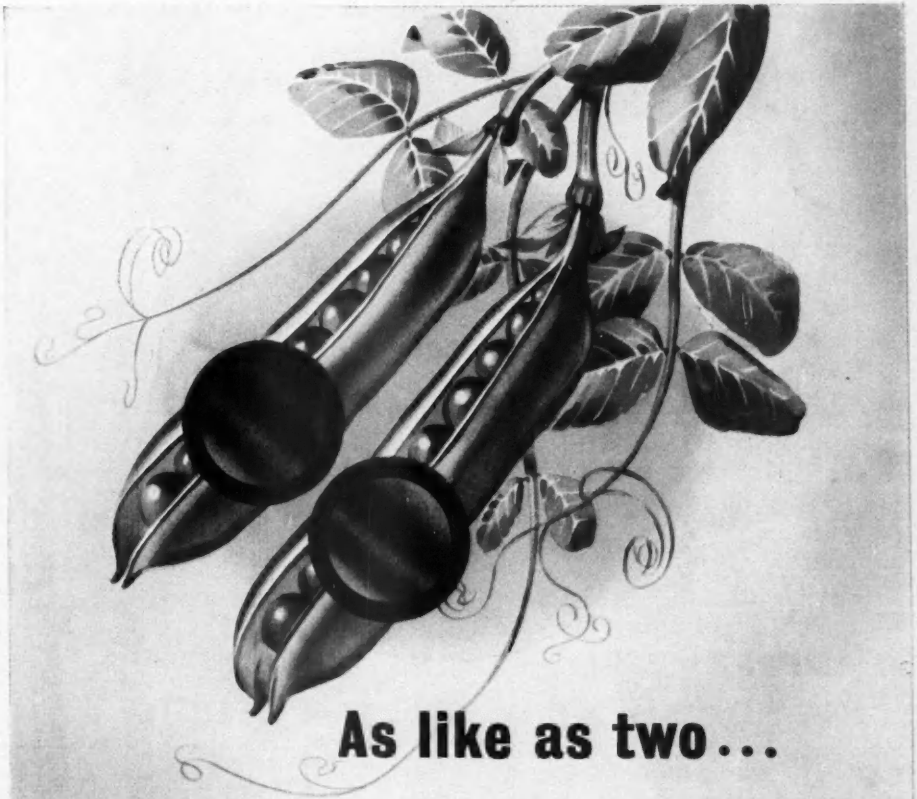

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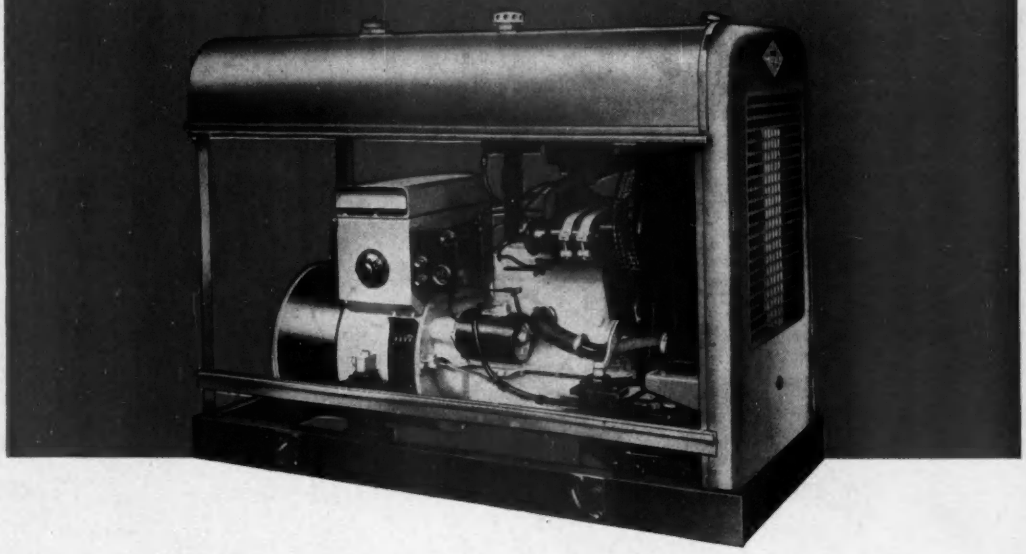

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- ★ Murex drooping characteristic generator.
- ★ Ford 10/30 h.p. Petrol Engine with constant speed governor.
- ★ Electric starting equipment provided for engine.
- ★ Output 20-250 amps, at 30 volts.
- ★ Shunt regulator for fine current adjustments.
- ★ Neat and compact canopy with sliding doors.
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